ARMY RESEARCH LABORATORY

M256 Static Load Test

Stephen Wilkerson
Virginia Fulton
Joe Thiravong

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A series of static load experiments was conducted on the M256 gun system to determine if clearances existed between its various components and, if so, where. In particular, it was desired to ascertain whether the gun tube and recoil mechanism act as a single unit or if clearances that exist between their primary parts allow the gun tube to deflect as a rigid body inside of the recoil device.

Of primary concern are the clearances between the gun tube and piston and between the piston and cradle assembly. The experiments were performed on a gun tube and recoil mechanism installed in a rigid floor mount and installed inside an M1A1 tank. This report details those experiments with a supporting finite element analysis.

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1. INTRODUCTION

The initial investigation into the M256 gun system and its components centered around identifying the system's critical structural components and understanding how they are fastened together. Therefore, to better understand the test setup and procedures, a brief review of the gun tube's assembly within the recoil mechanism is given.

The gun tube's assembly within the recoil mechanism is made up of nine structural parts which need to be considered in a finite element model. These main structural members were determined by examining the drawings and specifications for the M256 system and by watching the assembly of the system during routine maintenance. Figure 1 shows a cutaway view of the gun tube assembly and labels the nine critical components. Within this assembly there are four major parts which interact with one another. They are the gun tube (Figure 2); the breech (Figure 3); the cradle assembly, which includes the piston spring (Figure 4); and the four pieces which snug the whole assembly together (Figure 5) (i.e., the adapter, bearing, king nut, and thrust nut).

The cradle assembly houses the recoil mechanism while acting as an interface between the tank turret and the gun tube. Internal to the cradle assembly is the piston which clamps to the breech while supporting the gun tube at several locations. The breech is clamped to the piston via a series of bolts (see Figure 6). The gun tube is inserted into the cradle and breech. On the breech end of the gun tube, there are a series of four engaging grooves, or threads, at 45° intervals opposite the grooves inside the breech. After the tube is inserted through the cradle and into the breech, it is rotated 45° so that the threads on the breech and gun-tube-end inside of two recoil mechanisms lock the assembly together. However, to enable the gun tube to be pushed easily through the cradle assembly and into the breech, the piston, which rides over the gun tube, has ample clearances. A bolt, on top of the breech, is threaded through the breech into a small indentation in the gun tube, preventing the tube from rotating. In order to tighten up the assembly, the adapter, bearing, king nut, and thrust nut are required. The adapter has a slightly conical-shaped wedge on its outside, while its inside conforms to the gun tube and slides over the tube. The bearing has a slightly conical inside shape which engages the adapter, like a wedge, to fasten the two parts securely to the gun tube. The king nut drives the bearing onto the adapter, securing these parts rigidly to the gun tube's surface (see Figure 7). Finally, the thrust nut threads over the bearing, pushing on the piston, and thereby putting the piston in compression and the gun tube in tension while tightening the whole assembly together. Figure 8 shows a computer aided design/computer aided manufacture (CAD/CAM) drawing of the approximated parts as they will be represented in the finite element model.

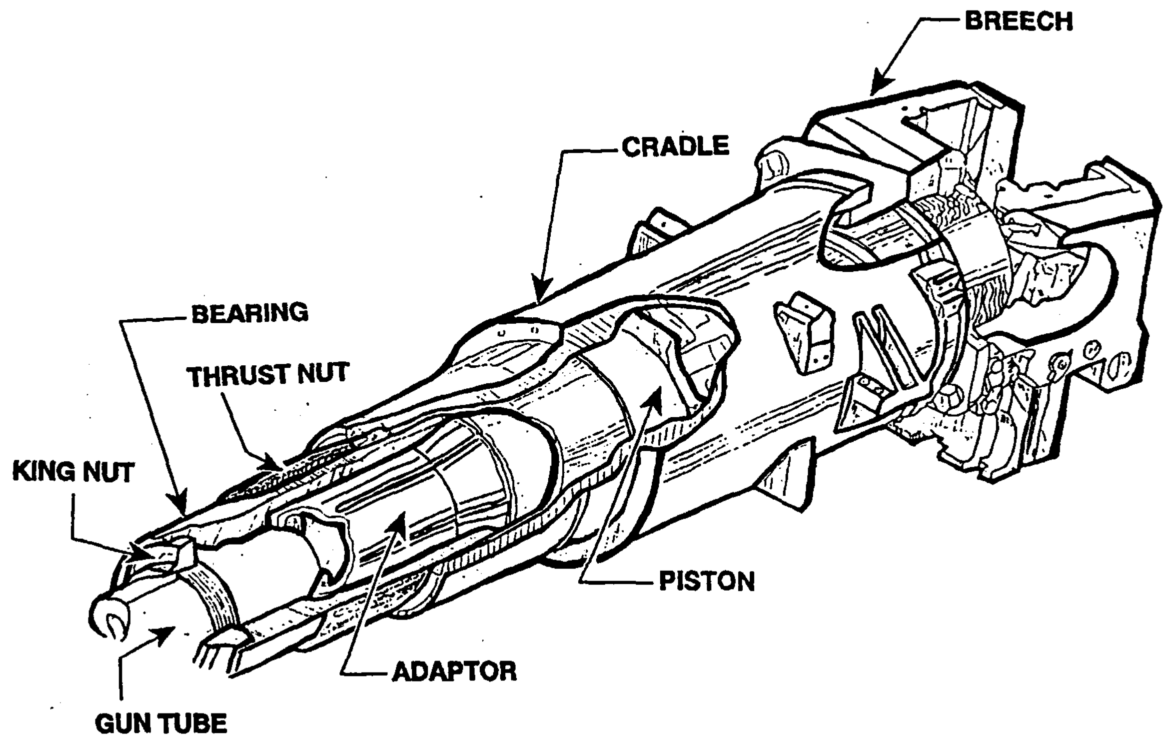

Figure 1. Cutaway view of gun tube assembly.

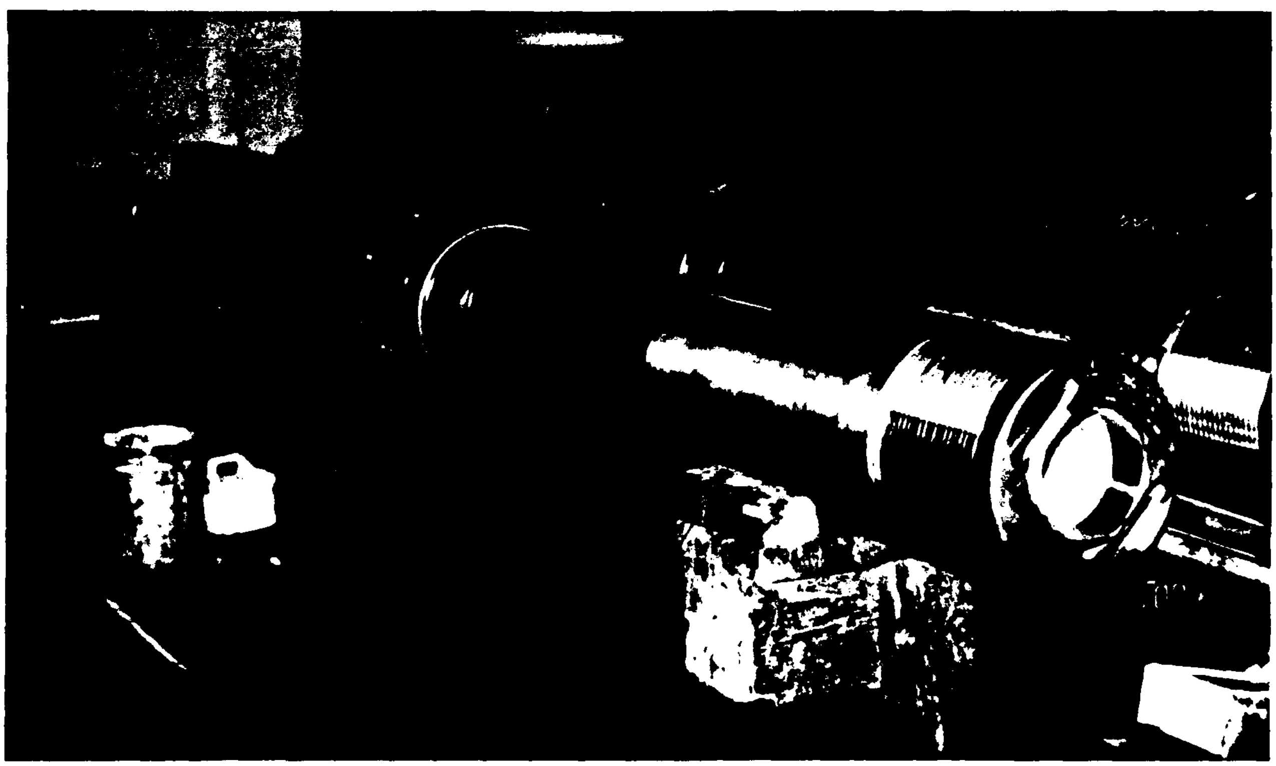

Figure 2. M256 gun tube.

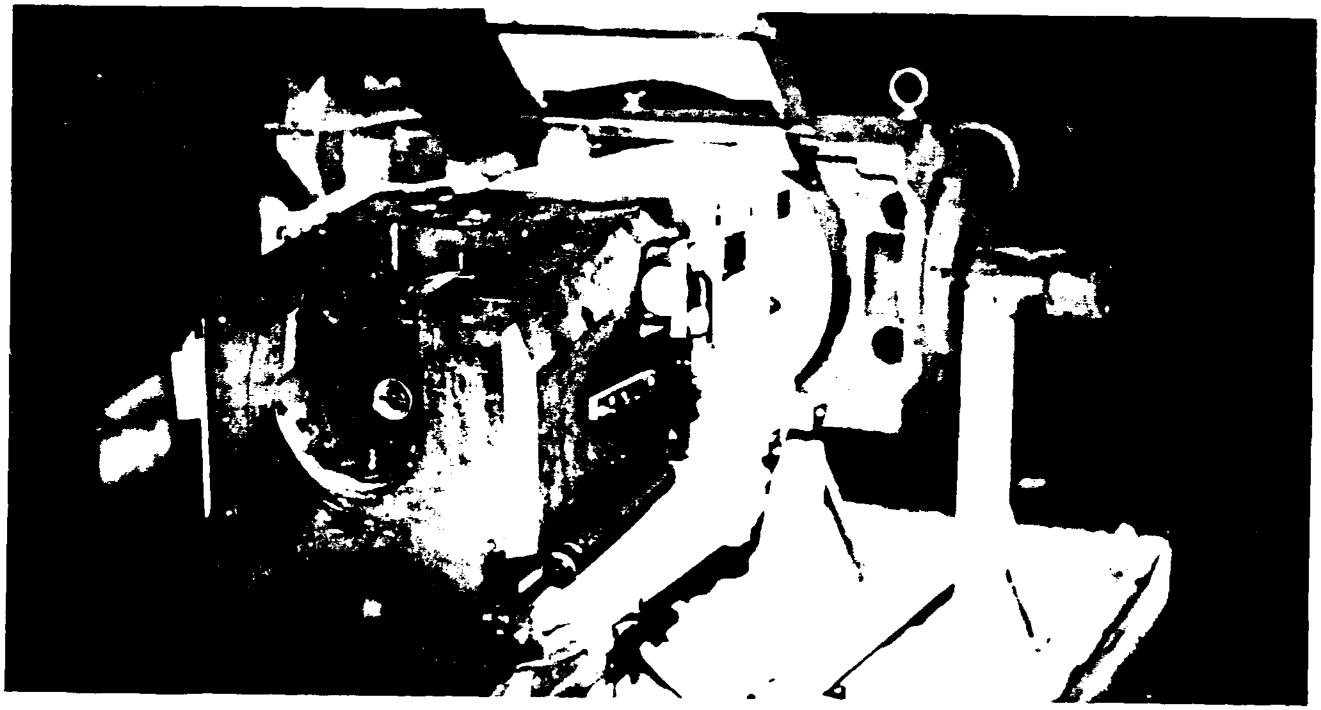

Figure 3. Breech.

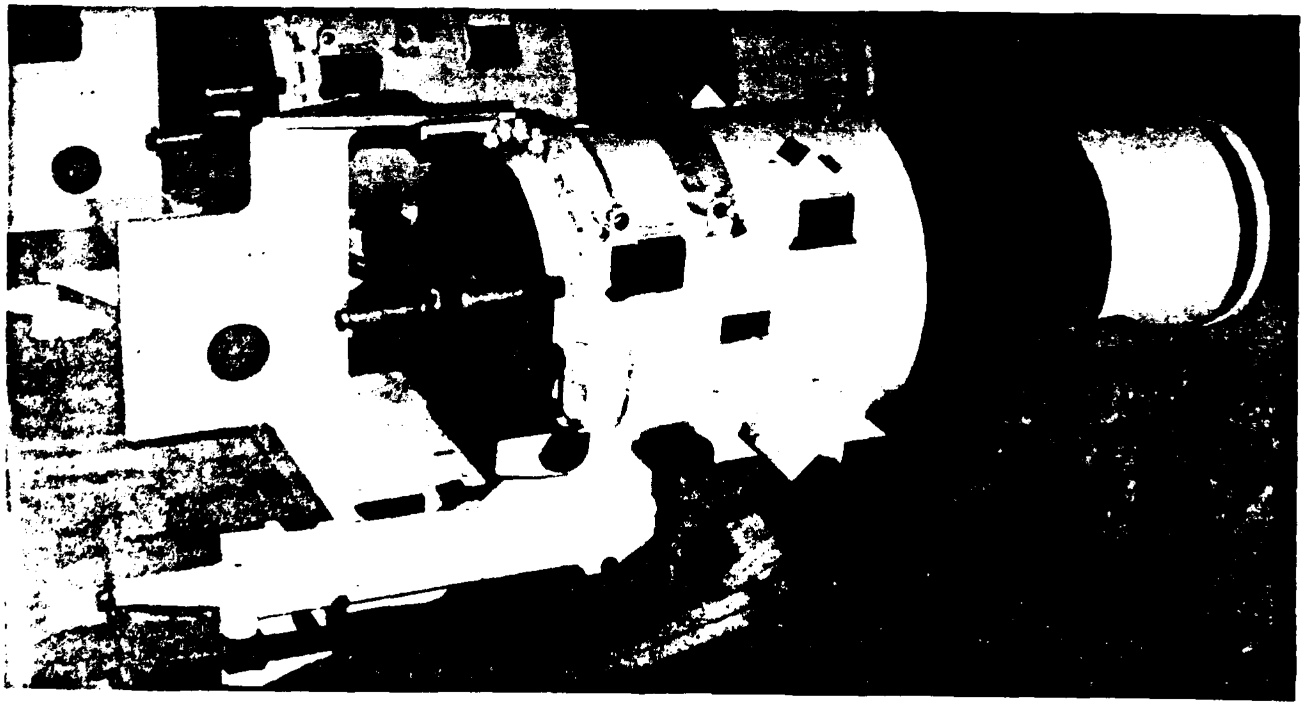

Figure 4. Cradle.

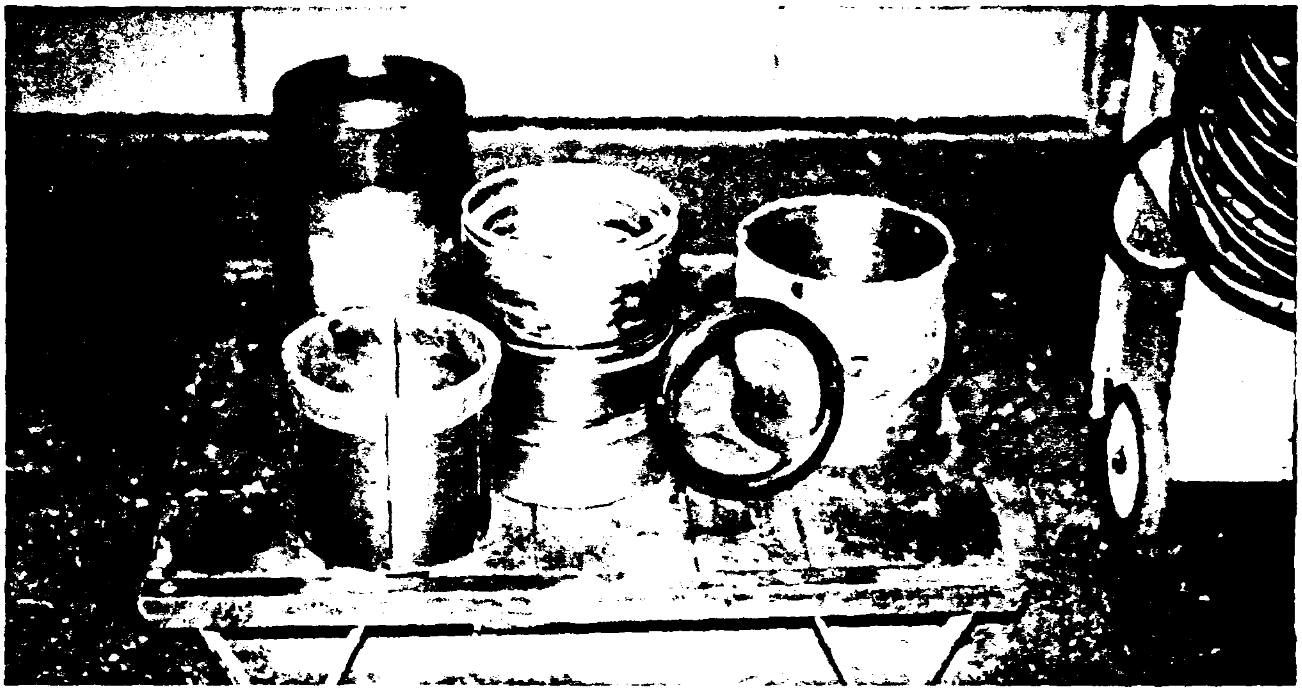

Figure 5. Left to right—adapter, bearing, king nut, and thrust nut.

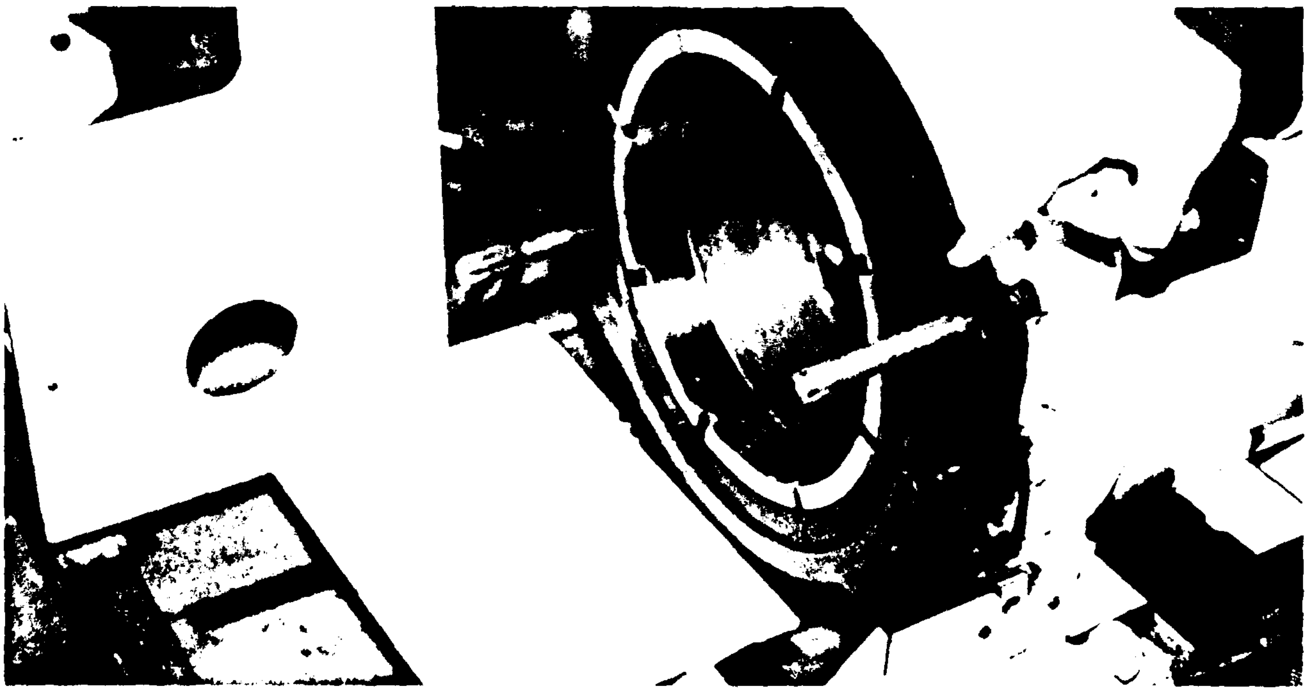

Figure 6. Bolts which attach breech to cradle.

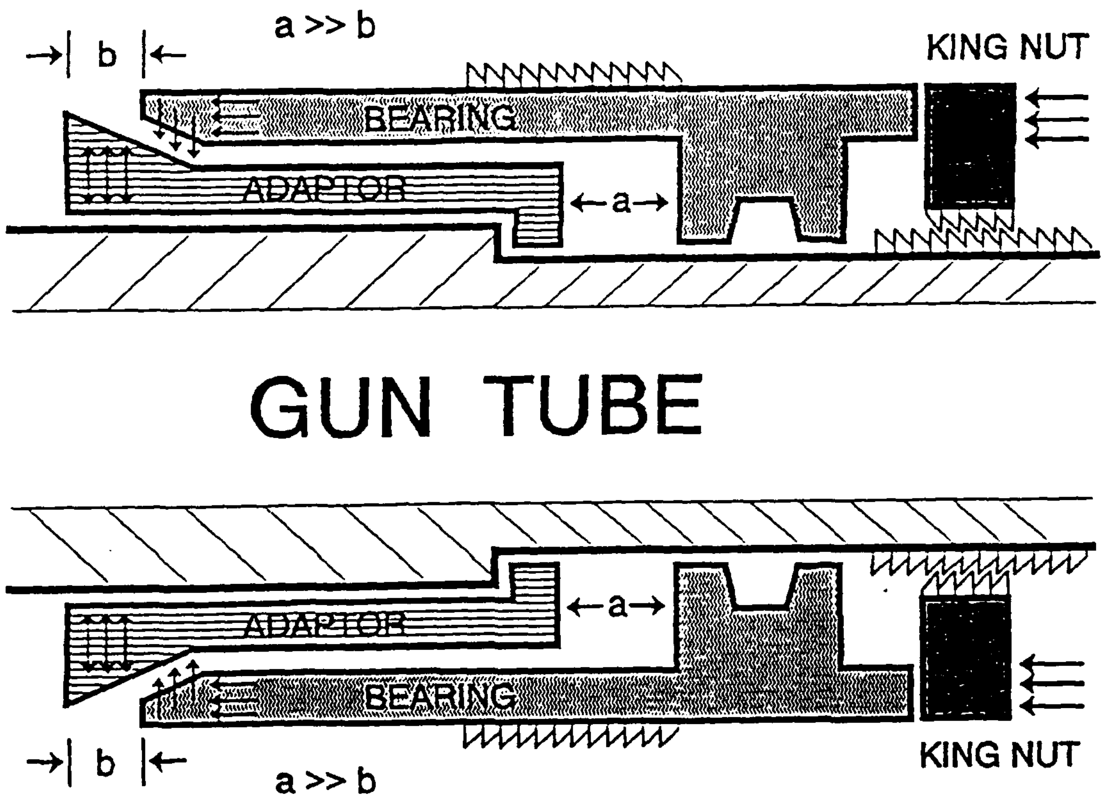

Figure 7. Adapter bearing and king nut clamping the gun tube.

Of primary importance in developing a finite element model of this mechanism was accurately determining the boundary conditions that exist between each of the parts (Erline et. al 1990; Hopkins 1990; Kaste and Wilkerson 1992). Of particular interest is whether the adapter, bearing, king nut, and thrust nut act with the gun tube as a rigid component or individually due to clearances. Initially, it was assumed that they acted as a rigid clamp. Similarly, whether or not the piston could be modeled as a rigid contact surface, where it clamps the gun tube, was equally important. It was hoped that this surface could also be modeled as a rigid contact. Finally, it was necessary to determine how to model the interface between the piston and cradle. Initially, it was understood that this surface needed to be modeled with sliding contact surfaces. However, whether or not additional clearances needed to be incorporated into the model was unknown. To determine these attributes required a simple series of tests. Therefore, a number of static load experiments were conducted to ascertain accurate boundary conditions to be used in the final three-dimensional finite element model of the gun tube recoil assembly. Those tests and what was learned are the subjects of this report.

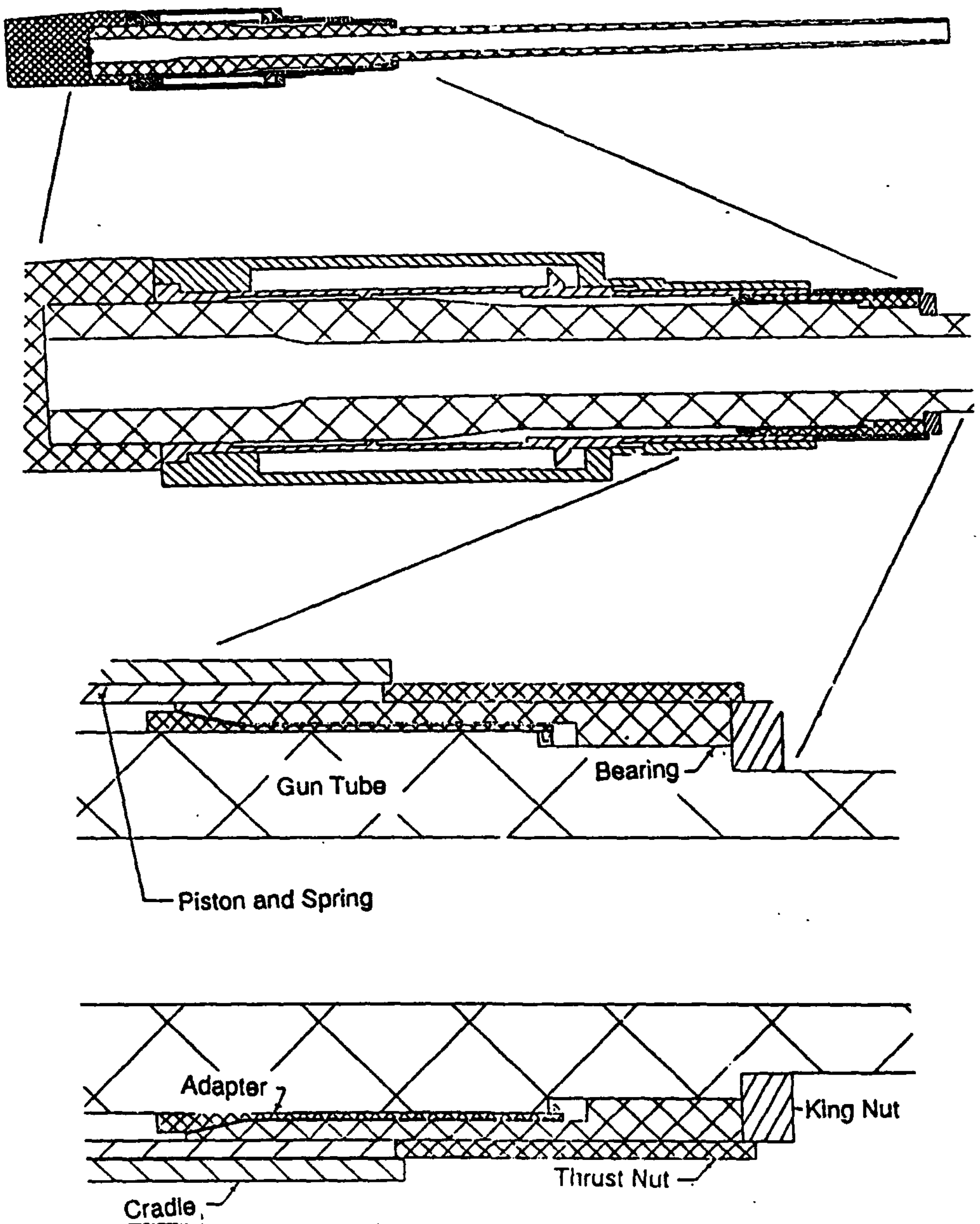

Figure 8. CAD/CAM drawing of M256 main components.

2. TEST PROCEDURE

The first objective was to see whether clearances existed between associated parts which would allow the gun tube to move independently of its mount (the cradle). A series of static load tests on the M256 system was used to answer the first objective. Basically, these tests consisted of lifting up on the gun tube at various locations with known loads while measuring displacements along the gun tube's length. After the first two test series, measurements were taken to determine if there existed relative displacements between associated parts as well. Additionally, the effect of the bearing, adapter, and king nut's torque, as well as the torque on the thrust nut, were examined while these parts were disengaged. The first five tests were conducted in a rigid gun mount, and then the final test series was done on a gun mounted in an M1A1 tank.

The initial test configuration consisted of an assembled M256 gun system mounted on a stationary platform (see Figure 9). The cradle was prevented from rotating about the trunnions by attaching a rigid jack screw between a stationary floor mount and the M256's elevating mechanism's bracket. This arrangement (see Figure 10) clamped the gun tube's mount rigidly to the floor platform in the horizontal position. After the test configuration was assembled, a "preliminary" series of tests was performed. In these initial tests and the five test series that followed, displacement gauge locations were referred to in terms of their distance from the end of the gun tube. Initially, the gun tube was marked every 10 inches along its length from the breech end. The M256 gun tube is approximately 208.7 inches long. Therefore, a location of 100 inches would indicate a position 100 inches from the breech end of the gun tube's length. On the other hand, a location of −5 inches would indicate a gauge location toward the back end of the breech. Additional information relevant to the test, like the load location, is also given in terms of the distance from the end of the gun tube. The load was applied via a crane. The crane was hooked to a load cell, and that cell was attached to a strap which was used like a sling to pull up on the gun tube. The sling arrangement had several advantages and some disadvantages. The biggest advantage of the strap was that it allowed the crane operator to gently adjust the load to the approximate target load for a particular test. However, the sling was made of a nylon material that slowly stretched under the load and released the tension on the gun tube. Therefore, once the load was applied and the recorder began reporting the gauge readings, the load was gradually released. Hence, after the initial tests, the load cell's measurements were recorded at the same time that the gauge was read. This was accomplished by having one person call out the load cell reading every second or so, while another recorded both displacement and load at each gauge location. (Note: the variations in load cell readings are slight.) Finally, prior to each test and once the slack was removed from the sling, each displacement gauge was zeroed. After the first two tests it was realized that it required approximately 200 lb of force to remove the slack from the loading apparatus, and, therefore, 200-lb loads were discontinued.

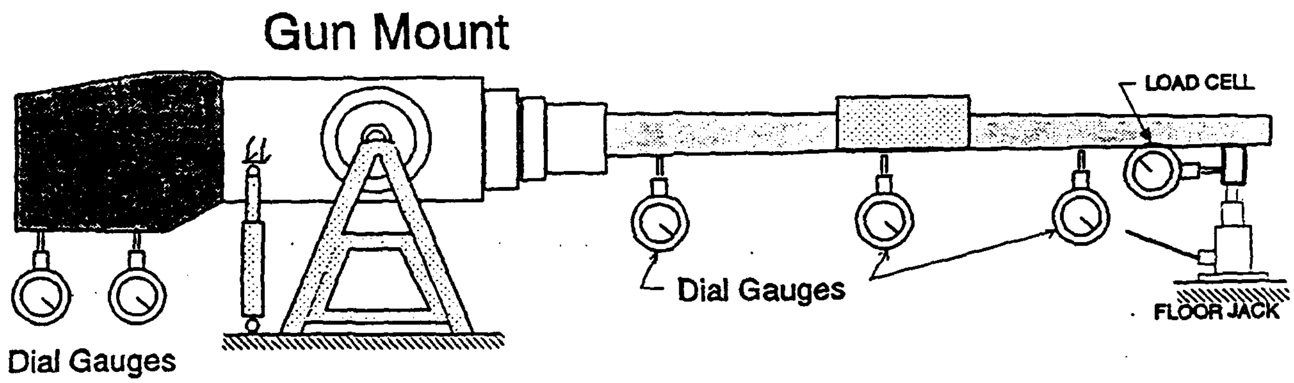

Figure 9. Gun mount test configuration

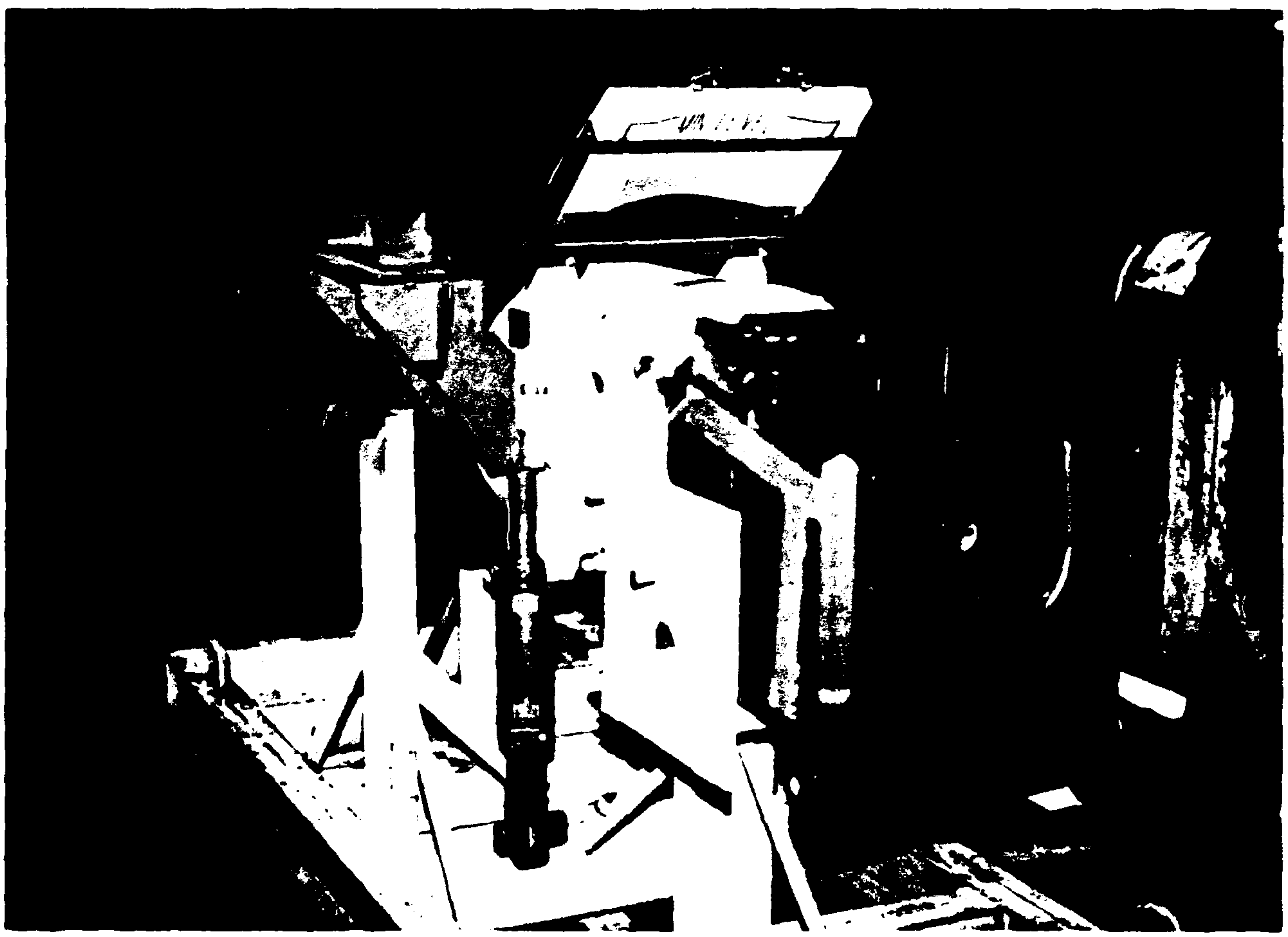

Figure 10. Rigid jack screw attached between rigid stand and cradle.

Some preliminary tests were made to check out the load cell and displacement gauges. In these initial tests, loads of 200 lb, 400 lb, and 500 lb were applied at the muzzle (206 inches) and at the tube's midpoint approximately 100 inches from the breech. After the initial tests, the 500-lb load was reapplied to see whether or not the results were reproducible. In fact, this procedure was used throughout the test series, and typically the first load condition was repeated and recorded. The tabular results from the first seven preliminary static load tests are given in Tables A-1 and A-2. The results are also plotted in x-y graphs where the abscissa is the axial position of the gauge and the ordinate represents the vertical displacement of the gun tube in thousandths of an inch (see Figures 11 and 12). Each displacement gauge was located along a vertical plane which passes through the centerline of the gun tube. Each position on the gun tube was located using a leveling device. In the preliminary tests, three gauges were spaced evenly between the tube's midpoint and muzzle, a fourth gauge was placed just beyond where the cradle clamps the gun tube, and the fifth gauge was placed near the rear of the breech. A final gauge was placed at the front of the stationary stand to assure that the stand was not tilting relative to the floor. It is important to note that inaccuracies were possible in the gauge readings due to the gauges' sensitivity and the way they were mounted. Consequently, any gauge which was bumped, touched, or even jarred slightly gave erroneous results, and in some cases this can be seen in the results. Each gauge was attached to a rigid bar or a flexible tube clamp, and magnets were used to secure the gauges to a stationary metal table just beneath the gun tube's center line. Magnet clamps did offer some advantages in that they made for easy adjustment, setup, and removal. (Nonetheless, during the tests, some gauges were jarred, and this problem is discussed when it can be observed.)

In order to understand the test data presented in this report, a brief overview of each test series is given. For each test series, tables are given which indicate the test conditions, loading, and displacements in tabular form. In addition to the tables, x-y displacement profiles are presented, summarizing the data in each table. The preliminary set of static load tests is summarized here as an illustrative example. Preliminary test "A" consists of a fully assembled M256 system in a test stand. The lifting load was applied at the muzzle approximately 206 inches from the breech end of the gun tube. Loads of 200 lb, 400 lb, and 500 lb were applied, and displacements were recorded at each gauge location. Gauges were placed at –9 (the back of the breech), 76.5, 120, 180, and 200 inches from the breech end of the gun tube. Additionally, one gauge was placed between the front end of the floor-mounted gun frame and the floor to see whether the loads were tilting the assembly. This gauge location is marked "floor" in the tables and is expected to always read zero displacement. Finally, after the initial test at 200 lb, 400 lb, and 500 lb, the tube was unloaded, the gauges were rezeroed, and the 500-lb load was repeated. Hence, gauge 1 reads –.0046 inches for the first test and –.0034 inches for the repeat loading. Some of the discrepancies between the results are believed to be caused by the relaxation of the sling used to apply the load. Therefore, after this initial series of tests, the actual load cell reading was recorded in the "read" column of the table at the same time that the displacements were recorded. Results from this test series are summarized in Figure 11 and in Table A-1.

Preliminary test "B" repeats test A with the load at 100 inches from the breech end of the gun tube. Results are summarized in Figure 12 and in Table A-2. In both of the preliminary tests, problems with the gauge rotating resulted in poor results; however, after these two preliminary test runs, care was taken in zeroing each gauge prior to the beginning of each test, and close attention was given to accurately reading the gauges at each load.

2.1 Test Series No. 1. The first test series consisted of a fully configured gun tube. The term "fully configured" is used to indicate that the thrust nut, king nut, etc., are tightly fastened and that the whole system is essentially set up as it would be in an M1A1 tank. The aim of the first test series was to record the results at each of the proposed load locations, for 200-lb, 400-lb, and 600-lb force. It was clear very early on that the higher loads (i.e., 600-lb force) applied toward the muzzle end of the gun tube would produce more consistent results. Nevertheless, for the first several test series, each load location and each load was applied, and the data were recorded. Gauges were placed at the back of the breech, just in front of the cradle-piston assembly 76.5 inches, and at 110 inches, 150 inches, and 170 inches forward of the breech end of the gun tube. One additional gauge was located between the floor and test stand although it seemed unlikely that these small loads would be sufficient to tilt such a heavy stand. A figure of the stand used in the test is shown in Figure 13.

Figures 14 through 19 show the displacement recorded at each of the load locations (i.e., 180 inches, 160 inches, 140 inches, 120 inches, 100 inches, and 80 inches, respectively). As can be seen in Figure 14, the results are, generally, what would be expected—that is, a gentle uniform curvature in the direction of the load. It is also important to keep in mind that the relative scale in which the displacements are plotted. Each plot was scaled in accordance with the minimum and maximum values of the data so that an exaggerated profile of the gun's tube shape could be seen. Two important boundary conditions applied in these static load tests are the locations of the two vertical supports. The first support is at the trunnions, around which the gun tube, breech, and cradle rotate freely. The second support was a jack screw that connected to the cradle housing near the breech. This should have prevented rigid body rotation of the system.

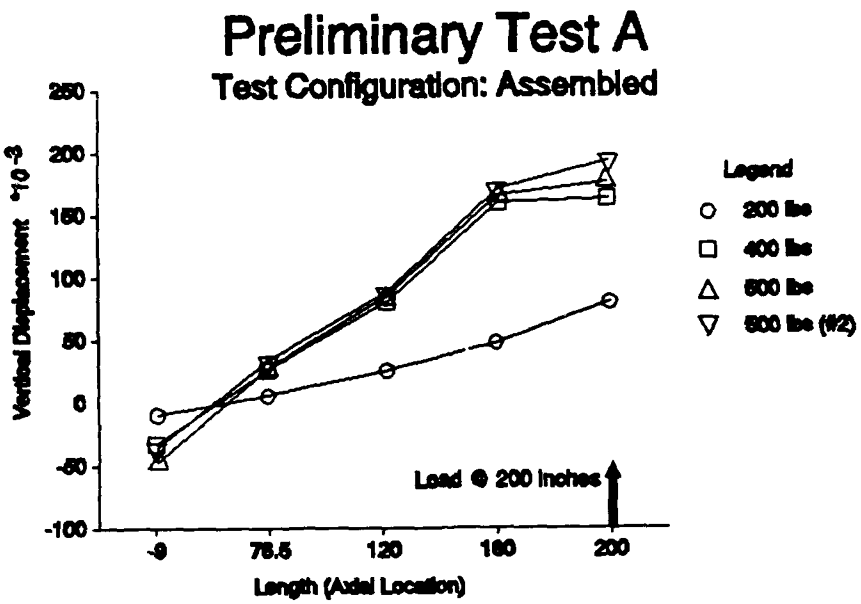

Figure 11. <u>Graphed data from preliminary test A</u>.

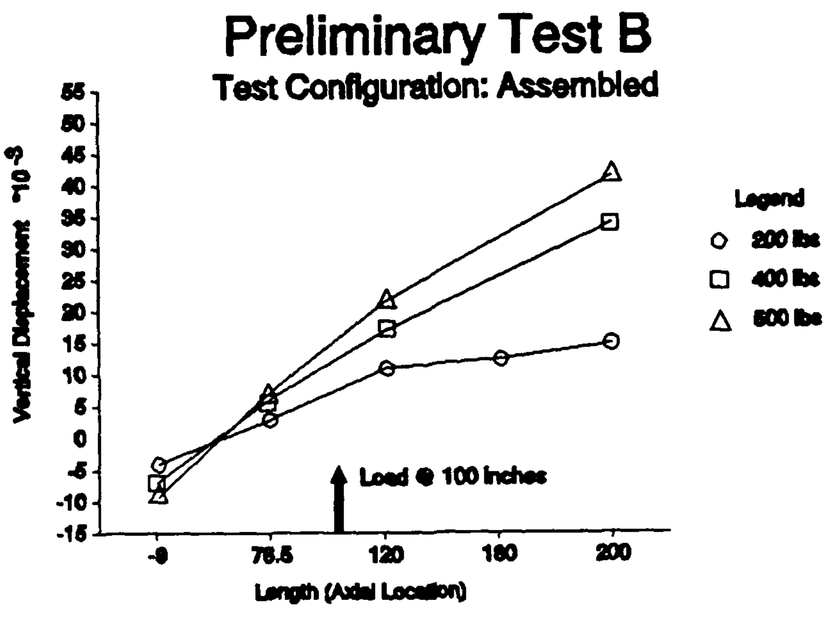

Figure 12. <u>Graphed data from preliminary test B</u>.

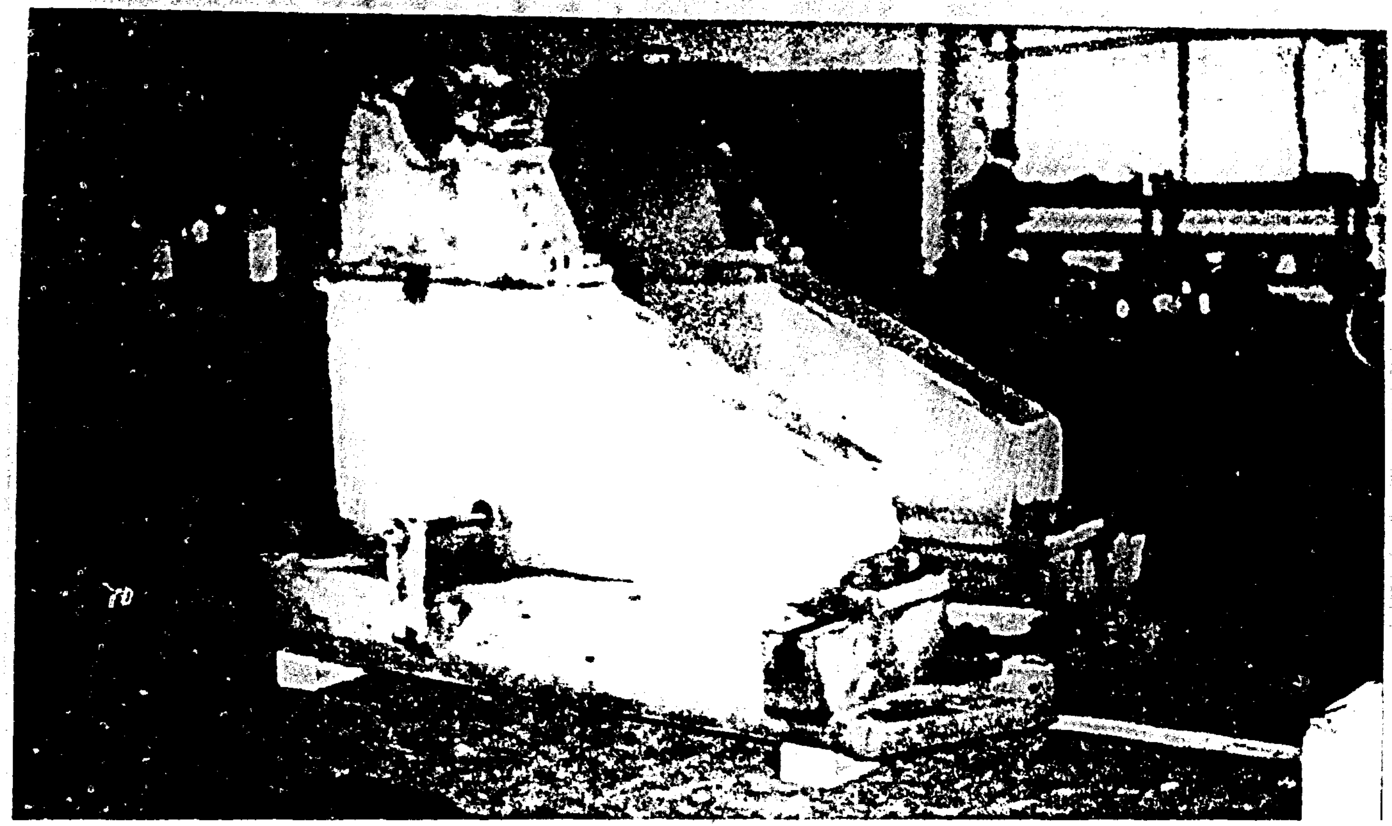

Figure 13. Test stand used in the static load experiments.

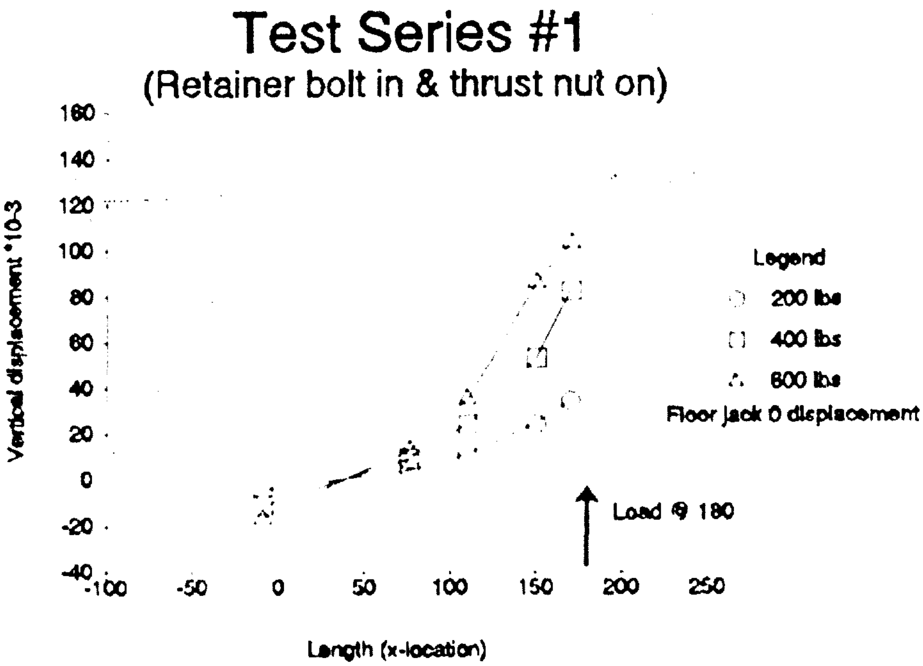

Figure 14. Gun tube loaded 180 inches from the breech end of the gun tube.

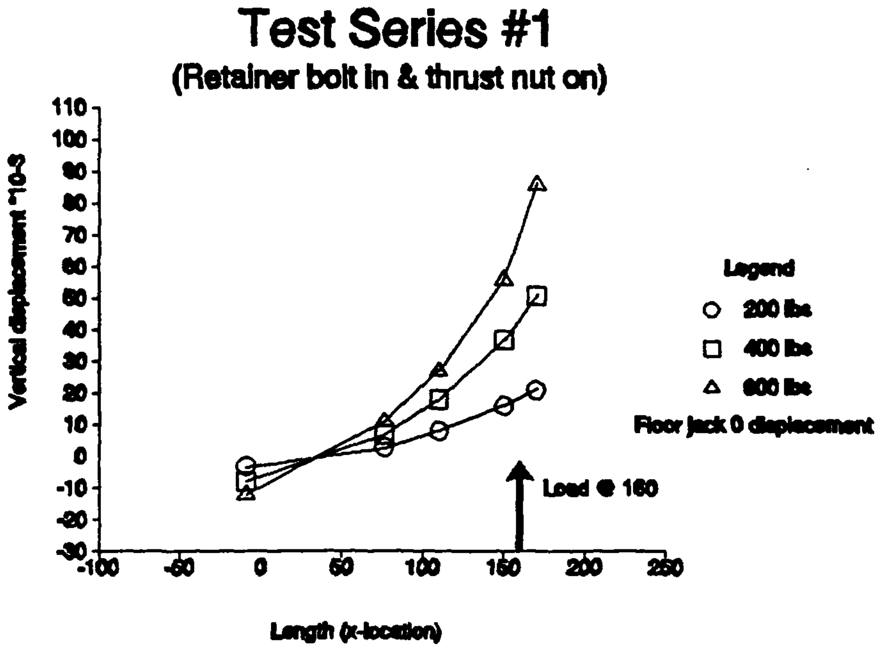

Figure 15. <u>Gun tube loaded 160 inches from the breech end of the gun tube.</u>

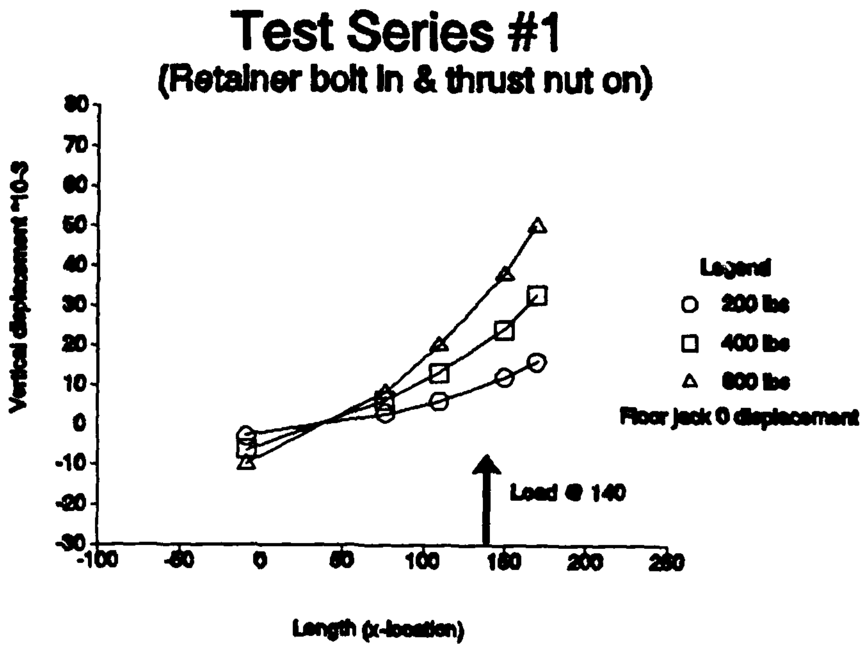

Figure 16. <u>Gun tube loaded 140 inches from the breech end of the gun tube.</u>

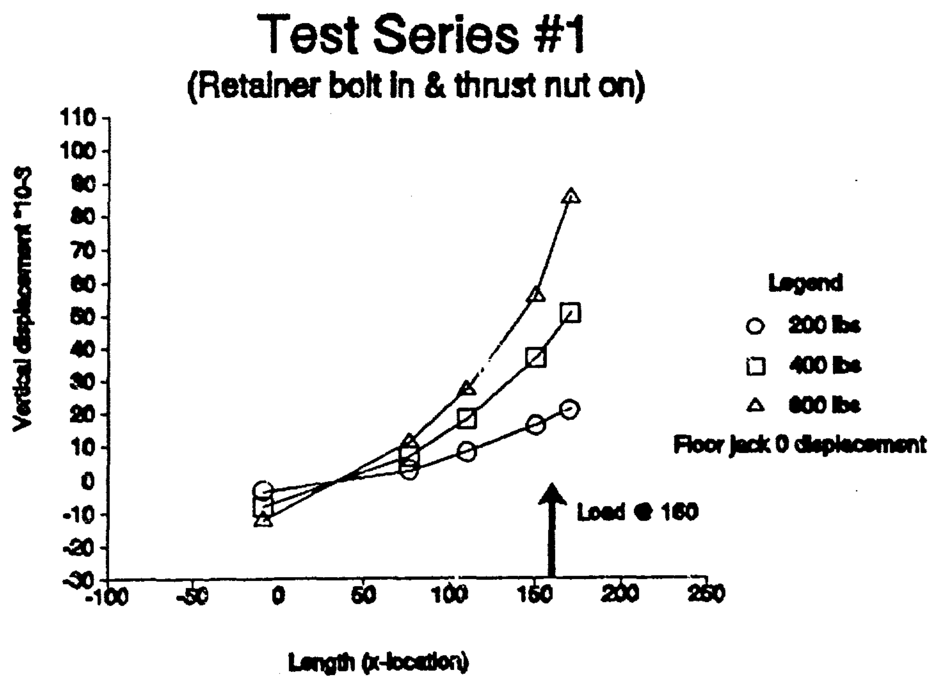

Figure 15. Gun tube loaded 160 inches from the breech ena of the gun tube.

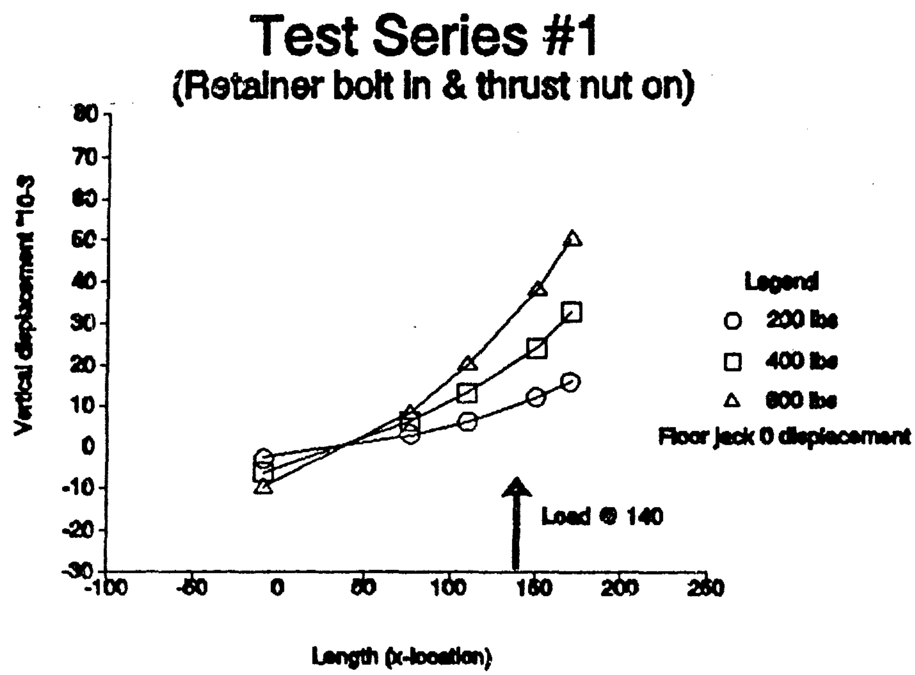

Figure 16. Gun tube loaded 140 inches from the breech end of the gun tube.

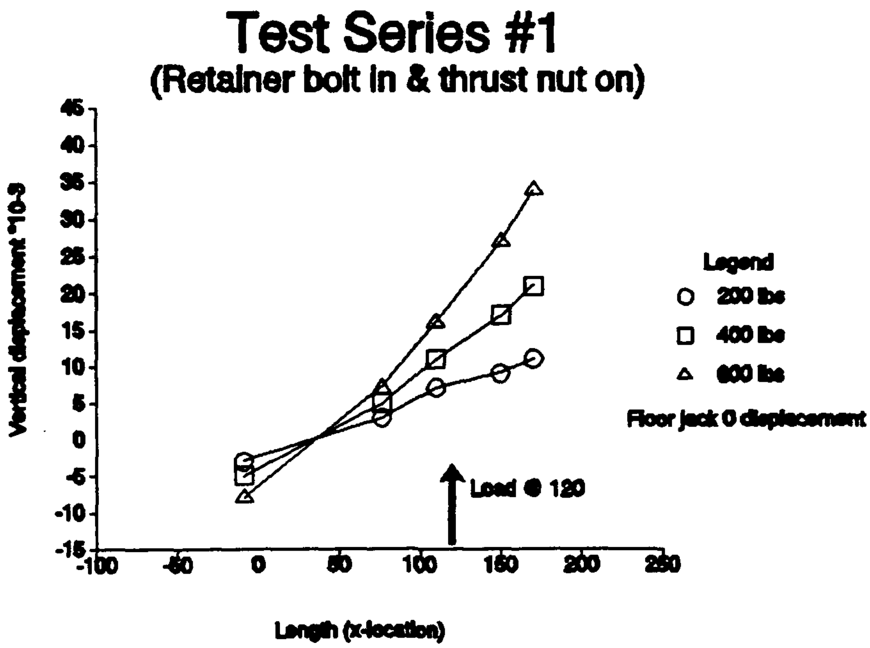

Figure 17. <u>Gun tube loaded 120 inches from the breech end of the gun tube.</u>

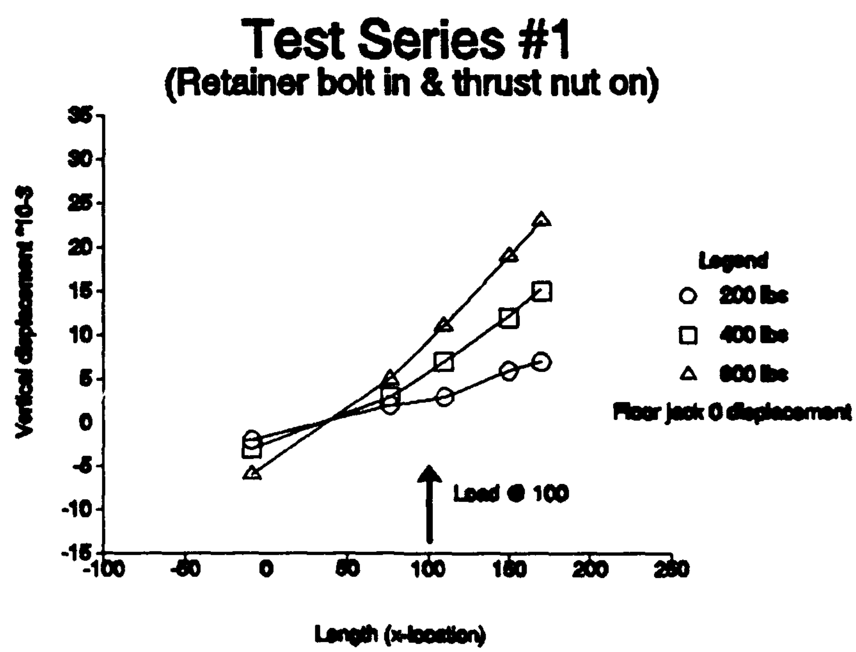

Figure 18. <u>Gun tube loaded 100 inches from the breech end of the gun tube.</u>

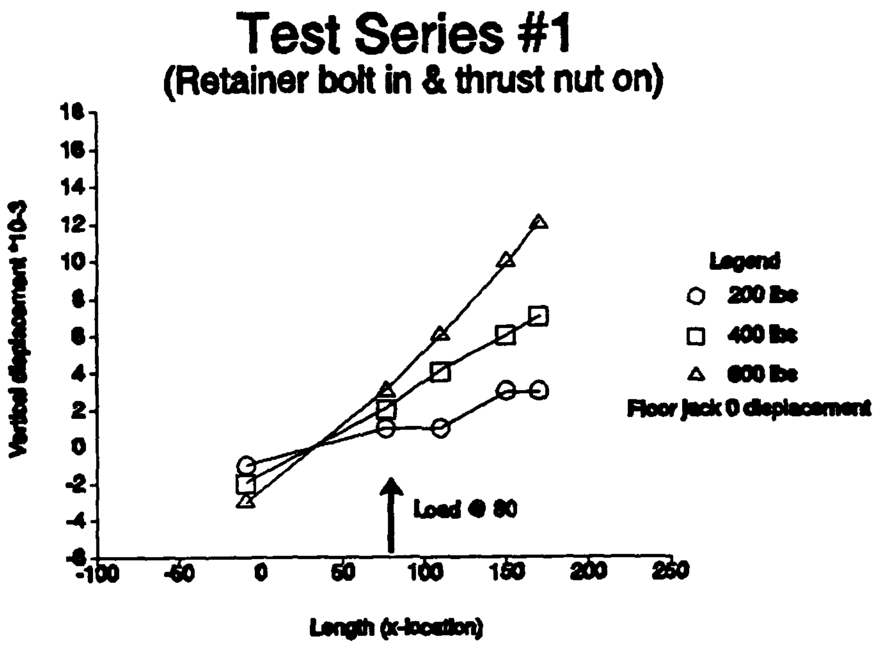

Figure 19. Gun tube loaded 80 inches from the breech end of the gun tube.

Nonetheless, the results indicate that a measurable rigid body rotation was occurring. Whether the rigid body rotation was the result of clearances between the piston and cradle, the piston and gun tube, or about the trunnion was unclear. This was due, in part, to the lack of gauges between those associated parts and the fact that no gauges at all had been placed on the cradle itself to determine whether it was rotating about its trunnions. It is important to note, however, that rotation about the trunnions was possible, independent of the jack screw, which was supposed to act as a rigid mount. For instance, clearances exist between the bolts and collars used to fasten the jack screw to the cradle. Further, the jack screw could also deform under the axial load of supporting the gun's rotation. Recalling that the displacement δ is proportional to the ratio of the load P multiplied by the length ℓ, to the modulus of the material E multiplied by the area of the axial member A (that is: $\delta = \frac{P\ell}{AE}$), then using a sample analogy that the 1 load P was on the order of 1×10^3 lb, the axial length was on the order of 5×10^2 inches, the modulus was approximately 30×10^6 lb/in^2, and the area was approximately 1 in^2, a displacement on the order of several thousandths of an inch was possible. Equally important to note is that the displacements being measured, with regard to the rigid body rotation, are of that same order. Therefore, it was clear that gauges would be needed on the cradle to determine whether rigid body rotation was occurring within the cradle assembly (i.e., being caused by clearances between parts) or by the cradle itself. Just the same, for the first two test series, gauges were left where they were. It was recognized that the rigid body rotation which was occurring, whatever its cause, could be investigated in subsequent tests by simply rearranging the gauge locations. This will be discussed later.

Also important to note in these figures is that each plot is graphed in accordance with the minimum and maximum values for that particular load condition. For example, Figure 14 has the maximum values on the order of 90 thousands, Figure 15 on the order of 85 thousands, Figure 16 on the order of 50 thousands, and so on. In other words, the magnitude of the displacements is decreasing as the moment being applied about the trunnion is decreasing (as would be expected). Therefore, Figure 19 with its load at 80 inches represents the smallest moment and, to no surprise, the smallest displacements as well. Hence, it is of little consequence that small inaccuracies in the gauge reading can be clearly seen for the 200-lb loads in some of the later figures; in as much as the 200-lb load, particularly when applied 80 inches from the breech-end of the gun tube, puts almost no structural load on the system and therefore only minuscule displacement. The data are further summarized in Tables A-3 through A-8.

As a quick check of the displacements, a finite element model was developed of the M256 gun tube, piston, cradle, and supports.

In order to incorporate the rigid body rotation as part of the finite element calculation, the elevating mechanism is approximated as a spring. The spring constant can be calculated by the measured rigid body rotation as observed at the breech. In the tables for all of the test series, this location is referred to as gauge position –9 inches. After the first two test series, which had only the gauge at position of –9 inches by which to measure the rigid body rotation, a second gauge was added at the elevation mechanism. Therefore, starting with test series no. 3, a gauge was placed at the elevating mechanism to verify the rigid body rotation. The gauge at the elevating mechanism proved that rigid body rotation was occurring and verified the displacements at the breech. Using the locations at the pivot point (the trunnions) and the location of the gauges, one at –9 inches and the other at the elevating mechanism, it was shown, using the law of similar triangles, that both gauge locations were obtaining nearly identical results. In fact, during the test it was possible to look at one gauge and estimate very accurately the reading of the other gauge. Nonetheless, calculating the rigid body rotation was accomplished by using the breech gauge reading. This was done in part since the rigid body rotation was more pronounced (larger) at the breech end of the gun tube than at the elevating mechanism and, therefore, could be measured more accurately there. A series of calculations estimating the spring constant of the rigid jack stand is given in Appendix B. As would be expected, there is some variation in these estimates for an equivalent spring to simulate the elevating mechanism (recall that the elevating mechanism for test no. 1 through no. 5 was a nearly rigid jack screw). This was due, in part, to the crude instrumentation and test setup to measure both the load being applied and the displacements being measured. Additionally, the gun tube alone weighs more than twice the maximum applied load and the whole M256 system weighs more than four times the load being applied. Coupled with the fact that the rigid body rotation was typically less than a hundredth of an inch, one would expect the consistency of the data to be considerably reduced. Examining the larger loads, however, particularly those applied at or near the muzzle end of the gun tube (thus, resulting in higher moments about the trunnion), resulted in more consistent spring constant estimates. Figure 20 shows a simplified graphical representation of the finite element model used in the following comparisons. The model uses beam elements to represent the gun tube, breech, piston, and associated parts as well as the cradle. The cradle is supported at the same approximate location as the actual M256 trunnion mounts, and a spring damper element is attached to the model at the same location as is the elevating mechanism. Then the load is applied at the same location as in the test, and the resulting displacement profiles are compared between the model and the results from the maximum load in Figures 14, 15, 16, and 17, which are given in Figures 21 through 24, respectively.

2.2 Test Series No. 2. The second test series consisted of a fully configured gun tube and mount where the torque on the thrust nut was completely released. This was done to examine the effects of variations in thrust nut torque on the clearances between the piston and gun tube—that is, whether the clearances which allow the gun tube to be assembled within the cradle, allow the assembly to move independently of their associated interfaces, and whether the torque on the thrust nut affects this phenomenon. In as much as test series no. 1 had the thrust nut on at the recommended torque and test series no. 2 removed the thrust nut completely, it was felt that this would give an estimate of the magnitude of any possible displacements between associated parts. As it turned out, whether the thrust nut was on or off for those tests made little difference in the observed displacements between the associated parts in the M256 at the loads that were applied. Figures 25 through 30 summarize the displacement profiles of the gun at each of the load locations performed for test conditions in test series no. 2. However, when considering the rigid body rotation, large variations in the calculated spring constant can be observed. Figure 31 compares the location of the load to the calculated spring constants for the elevating mechanism for the first two tests at the 600-lb load level. As can be seen from the results, only the first test series, which consisted of a fully configured gun system, gave consistent results.

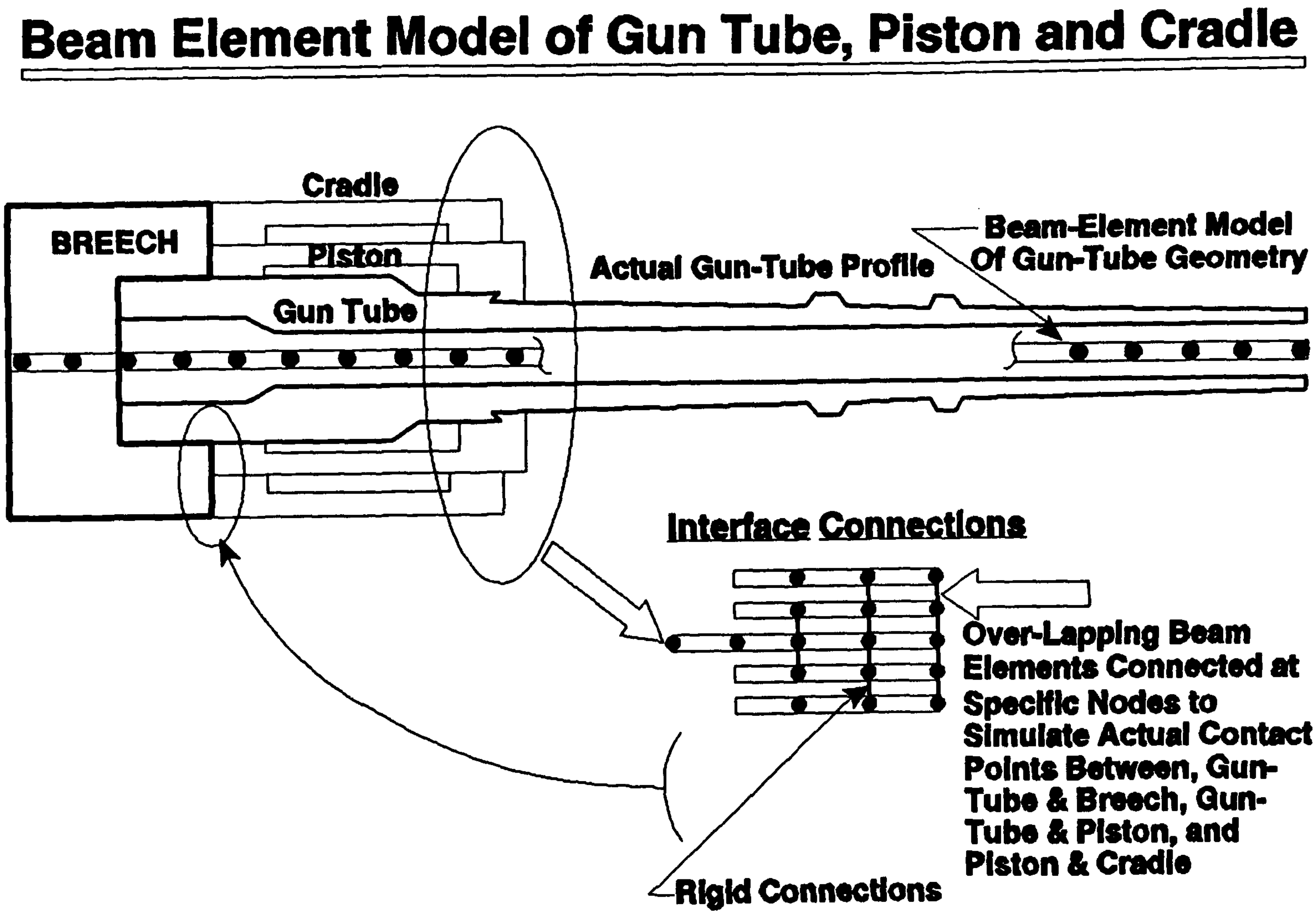

Figure 20. Finite element model.

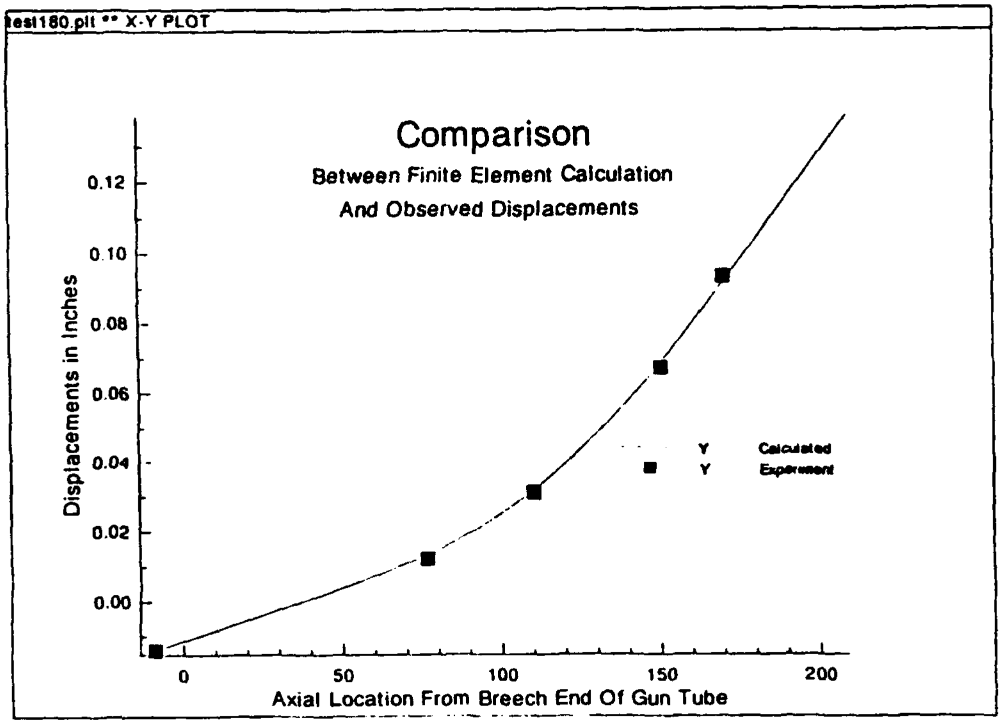

Figure 21. Comparison between calculated and observed displacements, test series no. 1, 600-lb load at 180 inches from rear face of gun tube.

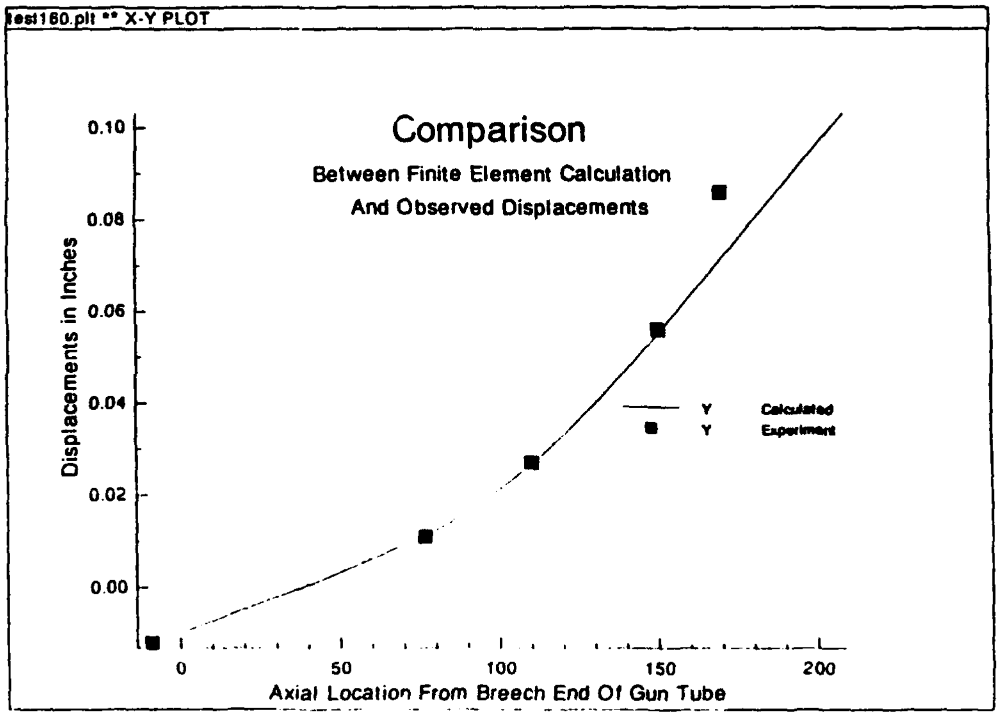

Figure 22. Comparison between calculated and observed displacements, test series no. 1, 600-lb load at 160 inches from rear face of gun tube.

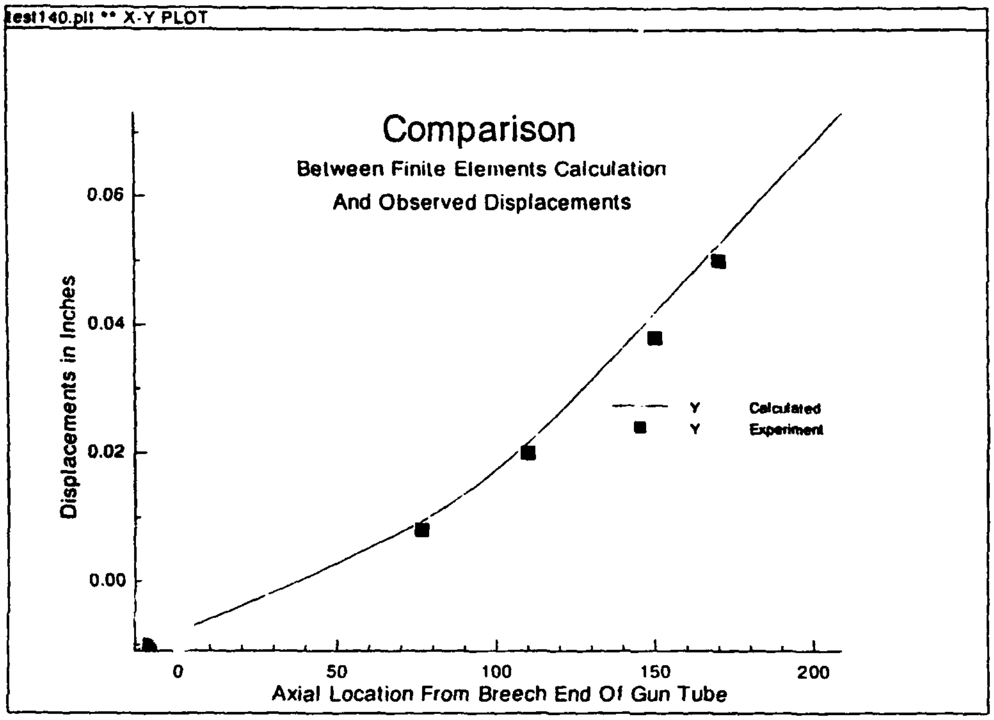

Figure 23. Comparison between calculated and observed displacements, test series no. 1, 600-lb load at 140 inches from rear face of gun tube.

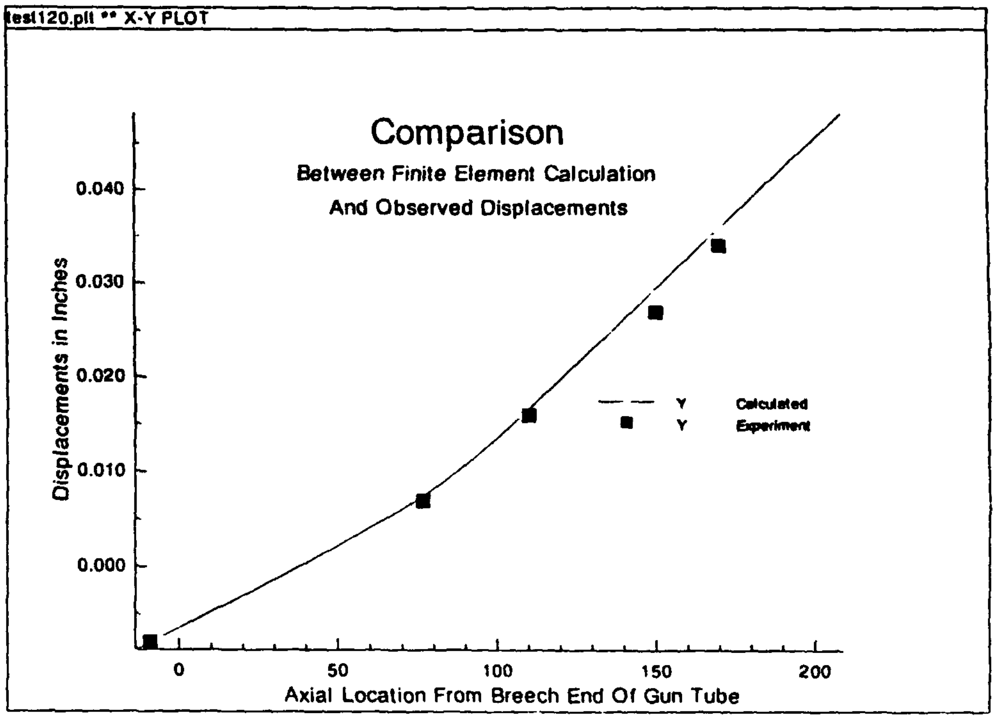

Figure 24. Comparison between calculated and observed displacements, test series no. 1, 600-lb load at 120 inches from rear face of gun tube.

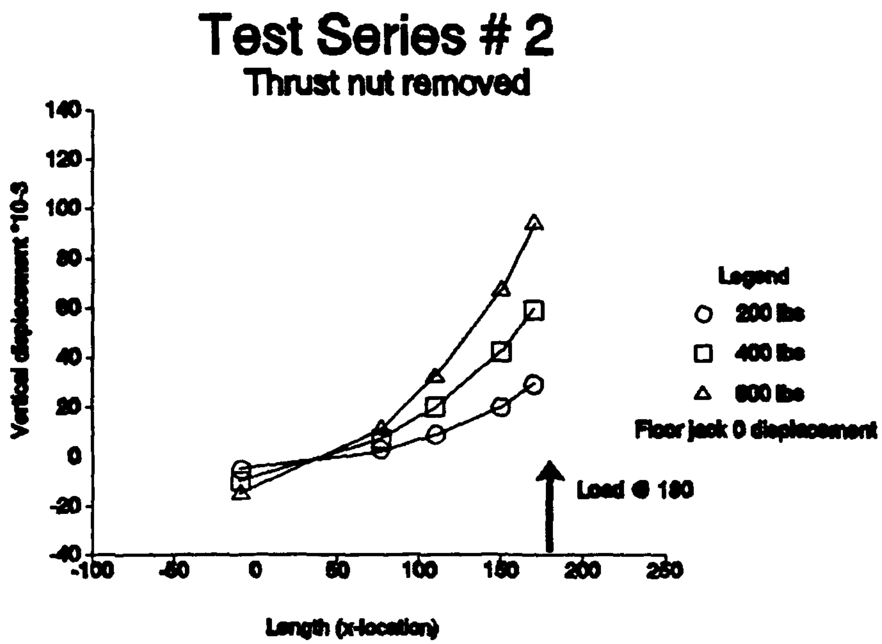

Figure 25. Gun tube load 180 inches from breech end of the gun tube.

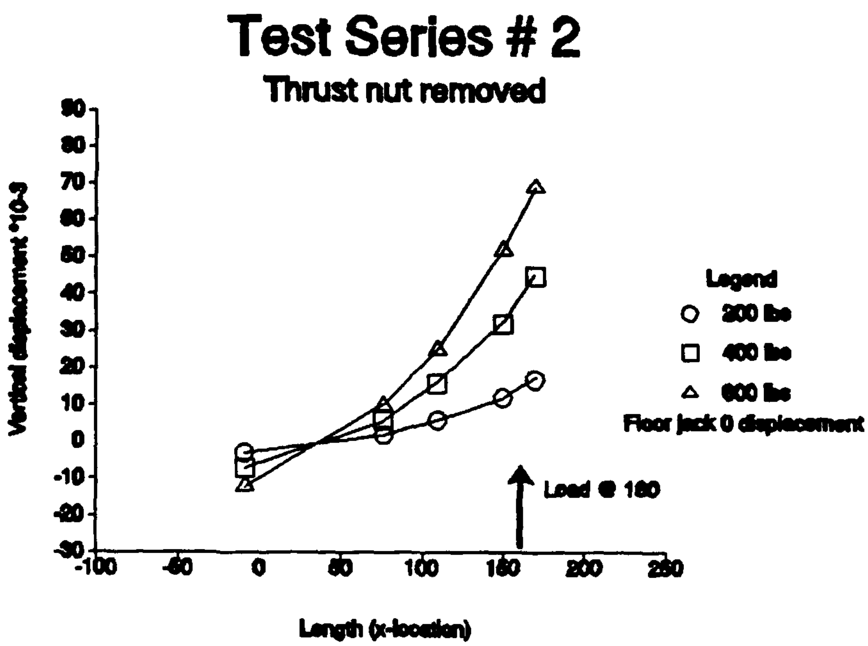

Figure 26. Gun tube load 160 inches from breech end of the gun tube.

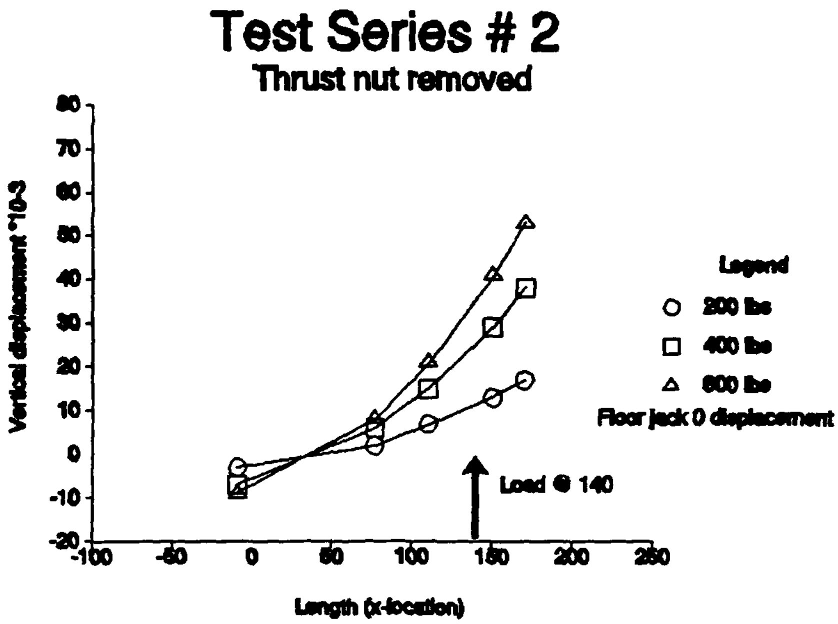

Figure 27. Gun tube load 140 inches from breech end of the gun tube.

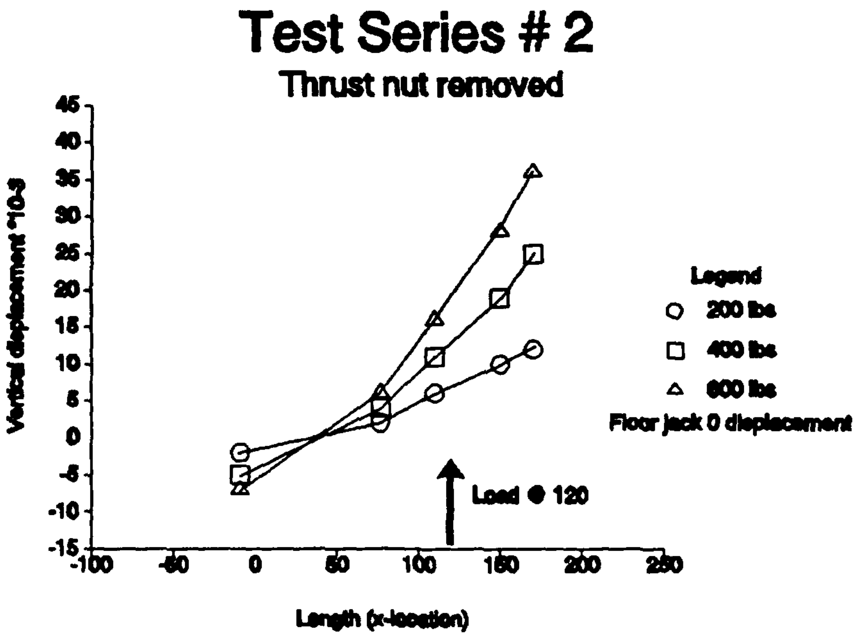

Figure 28. Gun tube load 120 inches from breech end of the gun tube.

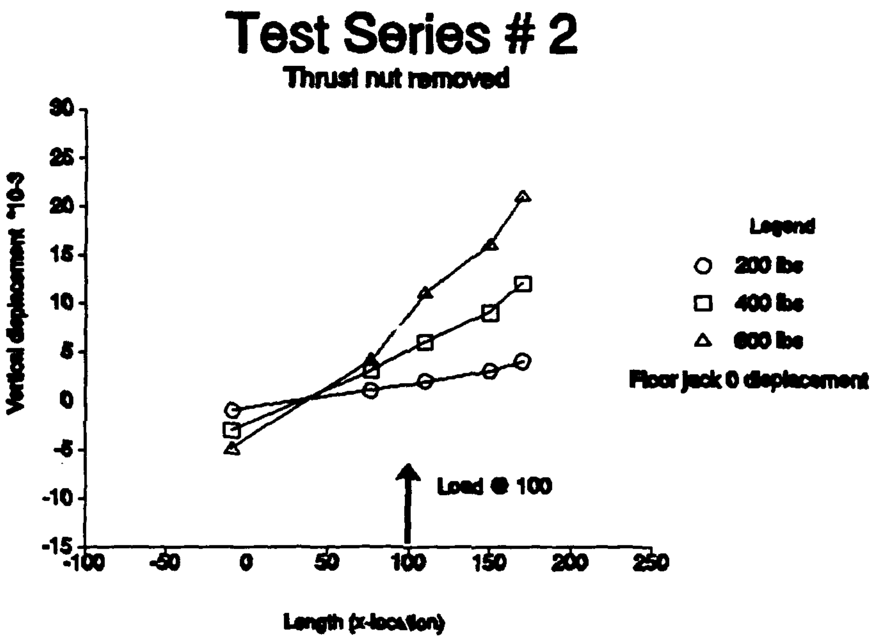

Figure 29. Gun tube load 100 inches from breech end of the gun tube.

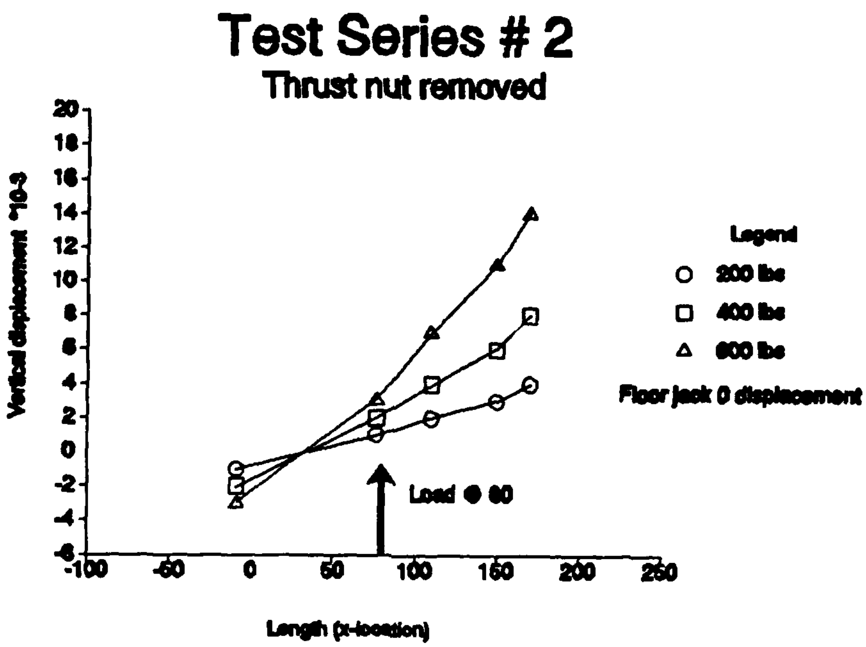

Figure 30. Gun tube load 80 inches from breech end of the gun tube.

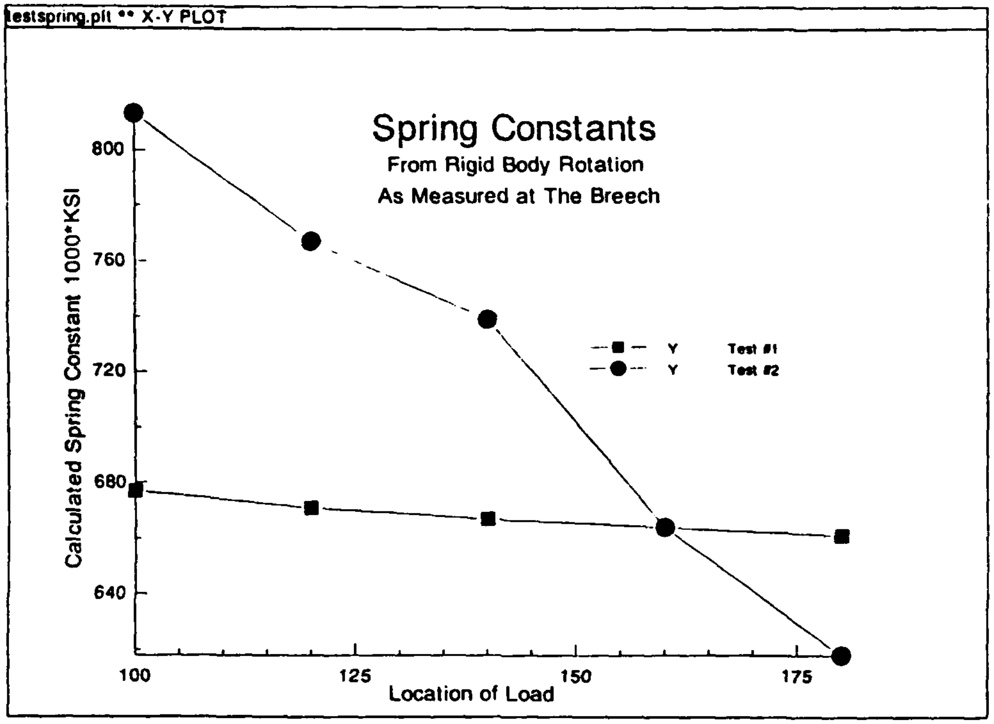

Figure 31. Spring constants vs. load location from test series nos. 1, 2, and 3.

Some of the inconsistencies could have been caused by sloppy recording procedures. However, the most likely cause was due to the gun-tube shifting its position within the cradle, and this is due to clearances between associated parts in the M256 assembly. With tests 3, 4, and so on, some of the parts were loosened, and therefore this explanation seems plausible.

2.3 Test Series No. 3. While test series no. 2 examined the possible effect of a loose thrust nut (which reduced the axial tension induced by the thrust nut on the gun tube and piston interface), test series no. 3 examined the effects of clearances between the associated parts by loosening all of the interfaces. This was accomplished by removing the king nut while the thrust nut was still off. By releasing the torsion on both the king nut and the thrust nut, the maximum amount of clearance between the gun tube and piston was present in the system. This was a worst-case scenario where the only mechanisms restraining the gun tube and piston to the cradle at the front of the cradle were the mechanical clearances that existed between those associated parts. The results from this test series are summarized in Figures 32 through 37. As noted in the figures, the loads at 200 lb were discontinued for the reasons already discussed. Despite the clearances that existed in test series no. 3, the results for displacements and displacement profiles were similar to those of test series no. 1. The only noticeable difference between

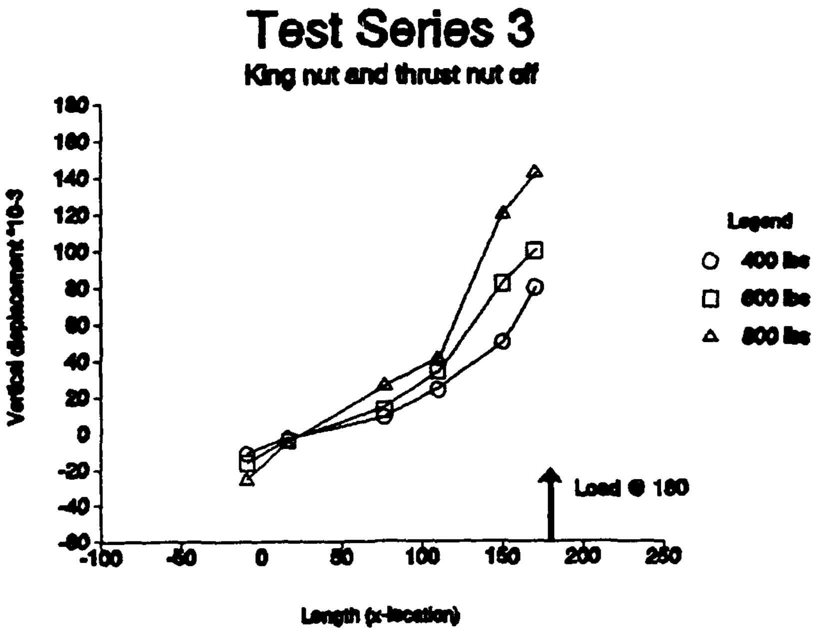

Figure 32. Gun tube load 180 inches from breech end of the gun tube.

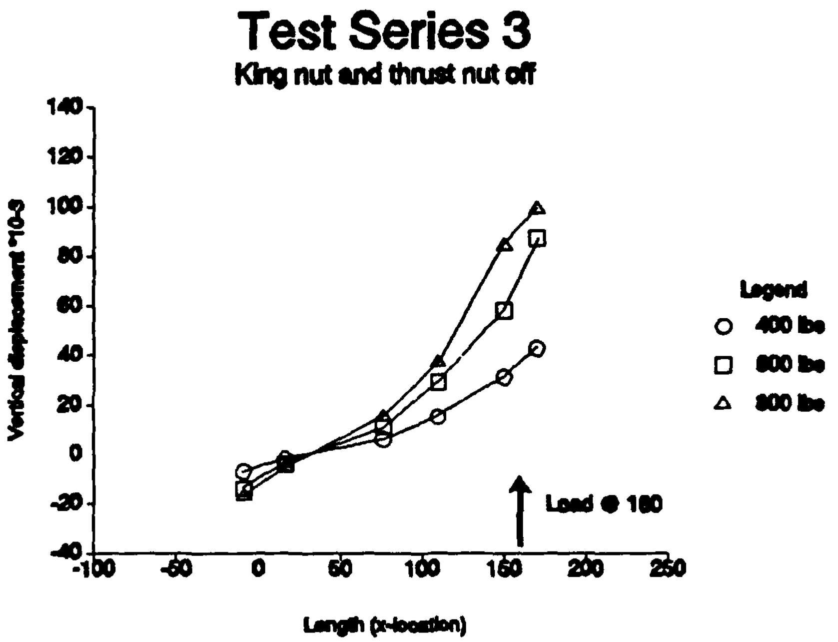

Figure 33. Gun tube load 160 inches from breech end of the gun tube.

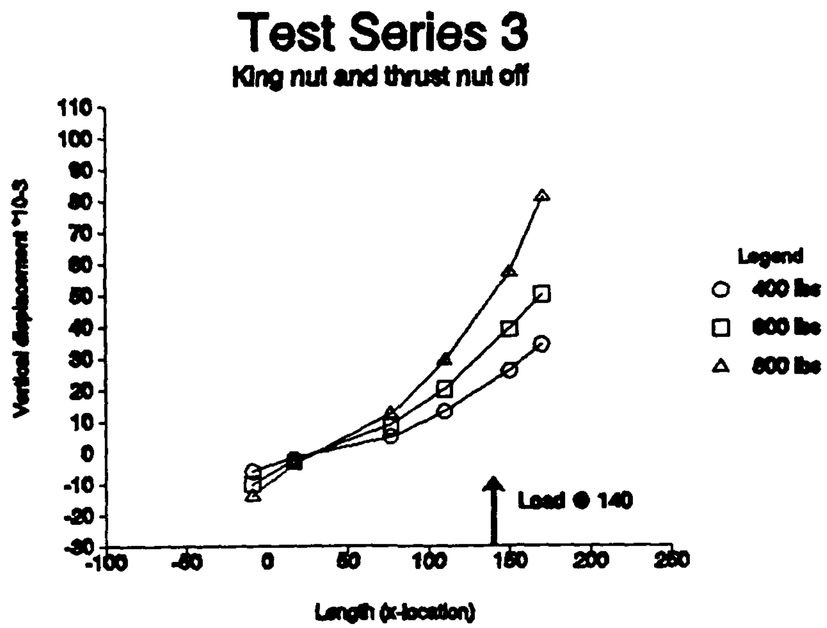

Figure 34. Gun tube load 140 inches from breech end of the gun tube.

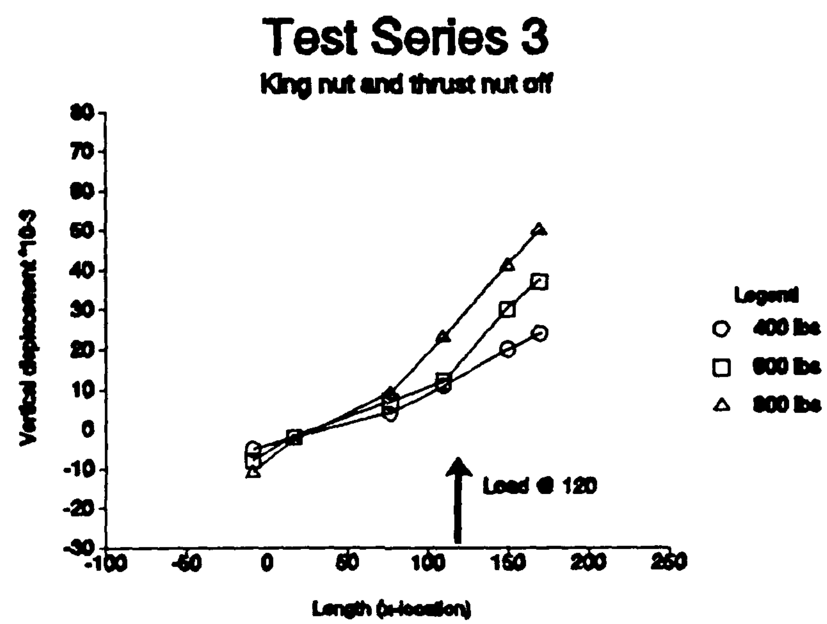

Figure 35. Gun tube load 120 inches from breech end of the gun tube.

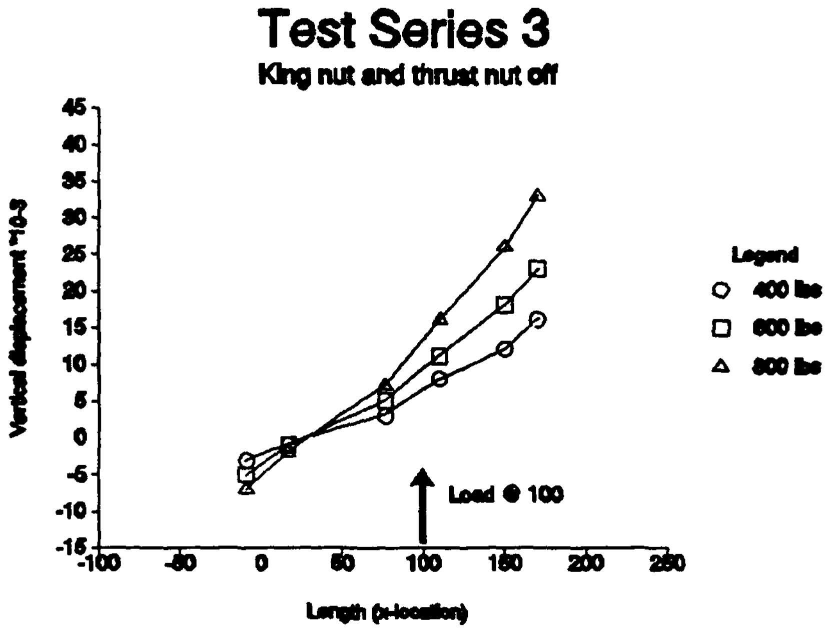

Figure 36. Gun tube load 100 inches from breech end of the gun tube.

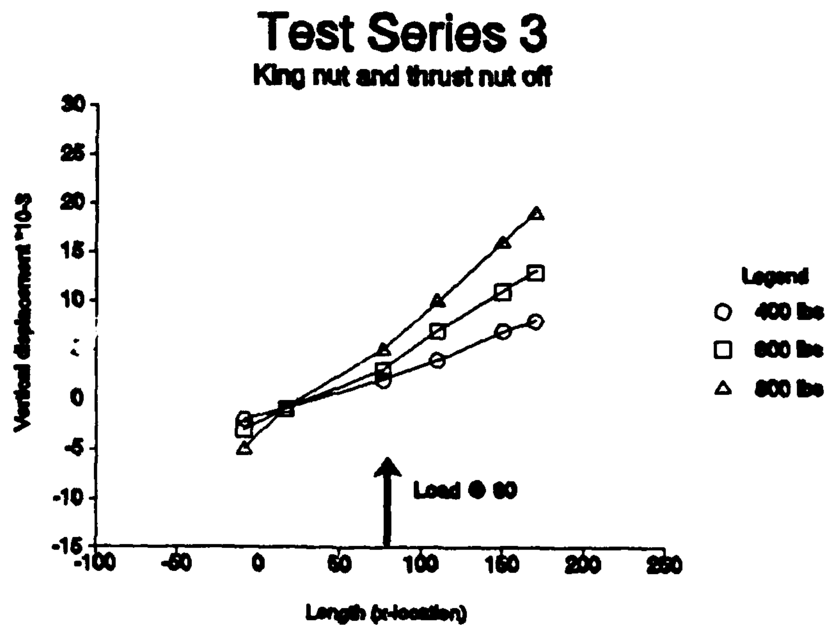

Figure 37. Gun tube load 80 inches from breech end of the gun tube.

the plotted results in test series no. 1 and test series no. 3 is that test series no. 3 profiles are not as smooth as those observed in test series no. 1. A smooth profile is what was expected. This could be caused by sloppiness in zeroing gauges or possibly by jarring the gauge mounts wh^n transitioning between load values. It could also be caused by the clearances in the assembly and the fact that both the thrust nut and the king nut were disengaged.

2.4 Test Series No. 4. Test Series no. 4 considered a fully configured gun system as in test series no. 1. However, two gauges were relocated to measure relative displacements between the cradle and piston and the piston and the gun tube. The loads were also increased to include loads up to 1,000 lb. In this series, loads were applied only near the muzzle. Locations near the muzzle produced a larger moment arm and enabled a significant load to be applied at the sliding interfaces inside the cradle. As loads are moved inward from the muzzle, as was done in the first several test series, the moment is less, and the load becomes insufficient to even lift the weight of the gun tube, much less load it. Therefore, the muzzle loading was more desirable since the test was limited in the extent to which a load could be applied. In any event, the results indicated that there was some displacements occurring between the cradle and thrust nut and between the thrust nut and gun tube which were on the order of the clearances between those parts. These results are summarized in Figures 38 and 39. The displacement reading of the gauges between the cradle and thrust nut and the thrust nut and the gun tube are indicated beneath the legends in these plots. Although these displacements undoubtedly contribute to the rigid body rotation being observed, they are smaller by comparison to those observed at the elevating mechanism for similar loads at the same location. It is also unclear from the results whether the gun tube and/or the piston is tilting within the cradle due to clearances or whether a slight deformation being observed is due to small deformations in the cradle and piston. Both are possible. However, the former is the most likely the cause of the deformations. The real question is how best to model these clearances and how these clearances will affect the dynamics of the overall system when it is fired. Undoubtedly, these clearances make it more difficult to model this phenomenon using a linear approximation.

2.4.1 Test Series 4A. As a final part of test series no. 4, a load was applied at the breech approximately 9 inches back from the rear face of the tube. If the deformations observed between the cradle and thrust nut and the thrust nut and gun tube were being caused by slight deformations in the associated parts, the gauges should have recorded a negative displacement. If, on the other hand, the displacements were occurring due to clearances between parts, th^se gauges should remain at zero. The results from this test are shown in Figure 40. As can be seen, the gauges remained zero throughout the

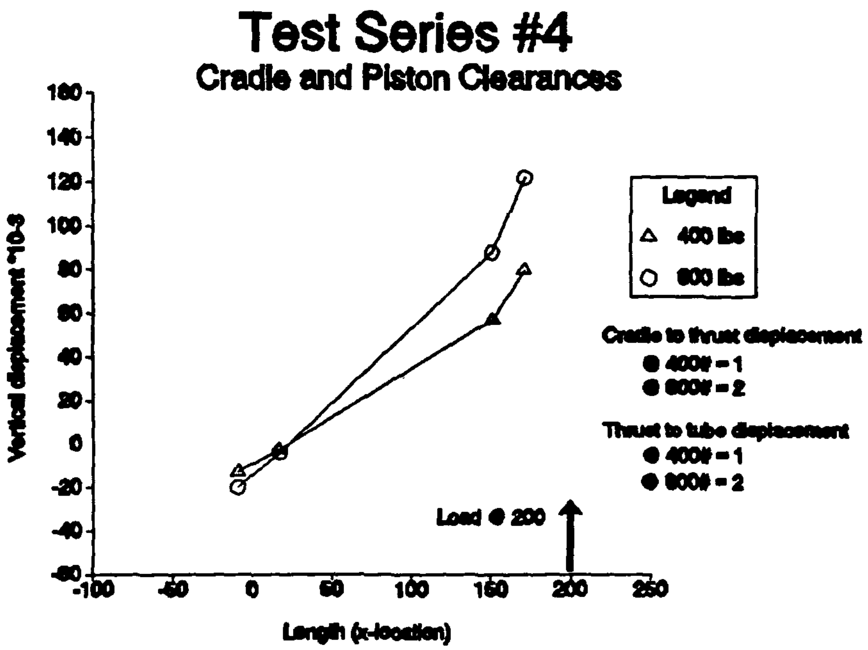

Figure 38. Gun tube load 200 inches from breech end of the gun tube.

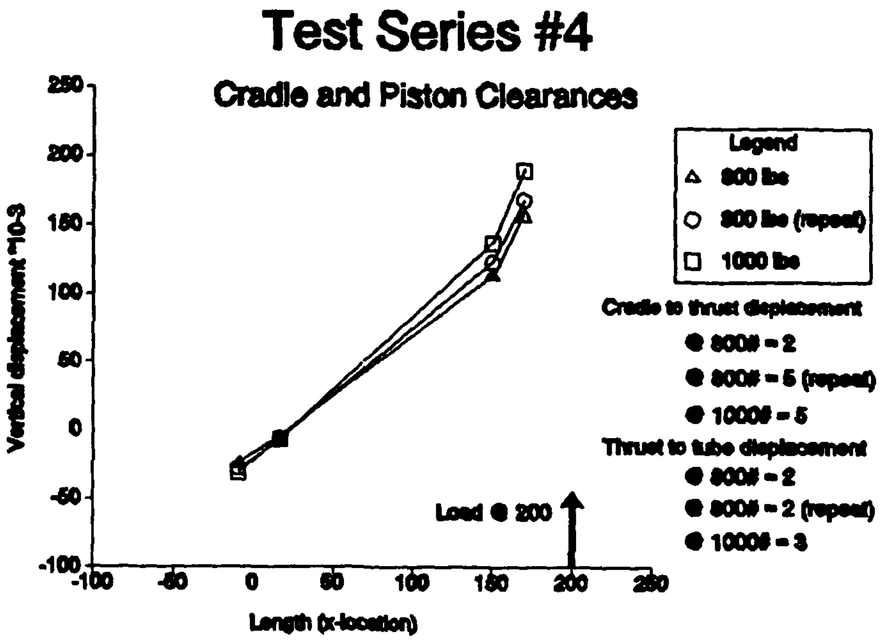

Figure 39. Gun tube load 200 inches from breech end of the gun tube.

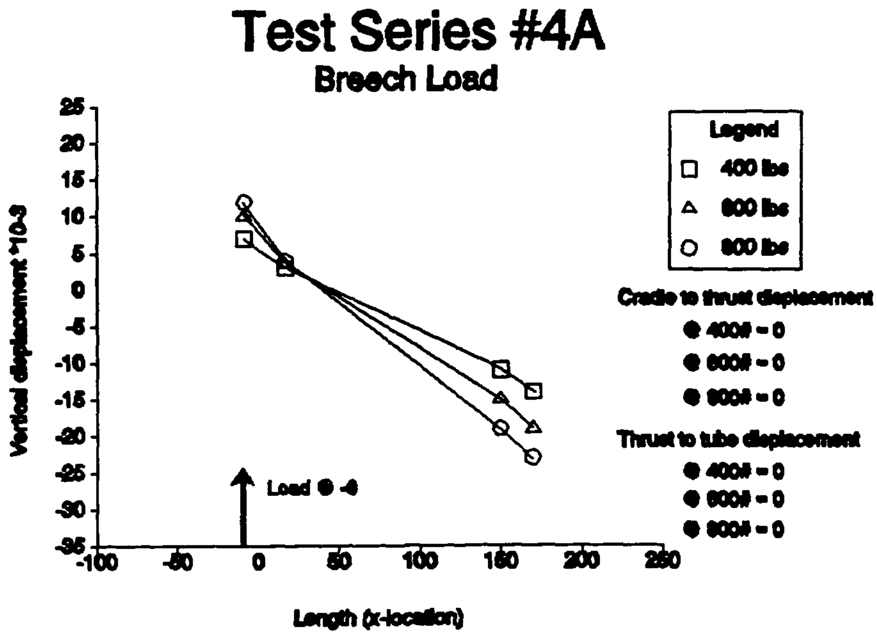

Figure 40. Gun tube load on breech end of gun tube.

loading sequences. This is a strong point for the argument that the clearances between the associated parts are the cause of the measured displacements in the previous test between the cradle piston and gun tube.

2.5 Test Series No. 5. There has been some speculation on the possible role of the retaining bolt in causing the breech to move downward during firing. The retaining bolt is located near the end of the gun tube on the breech. Basically, its purpose is to lock the gun tube to the breech by preventing the gun tube from rotating relative to the breech. The gun tube and breech are actually fastened together through a series of engaging threads which interlock upon assembly of the gun tube and breech. (See Introduction for further details.) While it was impossible to pressurize the gun tube during this test, it was possible to remove the retaining bolt and repeat test series no. 1 to see if there was any effect on the observed displacements. Once again, only the loads being applied close to the muzzle were repeated. The results of these tests are given in Figures 41 through 43. These displacement profiles are nearly identical to those observed in test series no. 1. It is also important to note that the displacements between the cradle and piston as well as between the piston and gun tube are considerably less than what was observed in test series no. 4. From this, it may be concluded that some displacement was occurring between these parts but that the methods and load levels used during this test series were insufficient to make definite

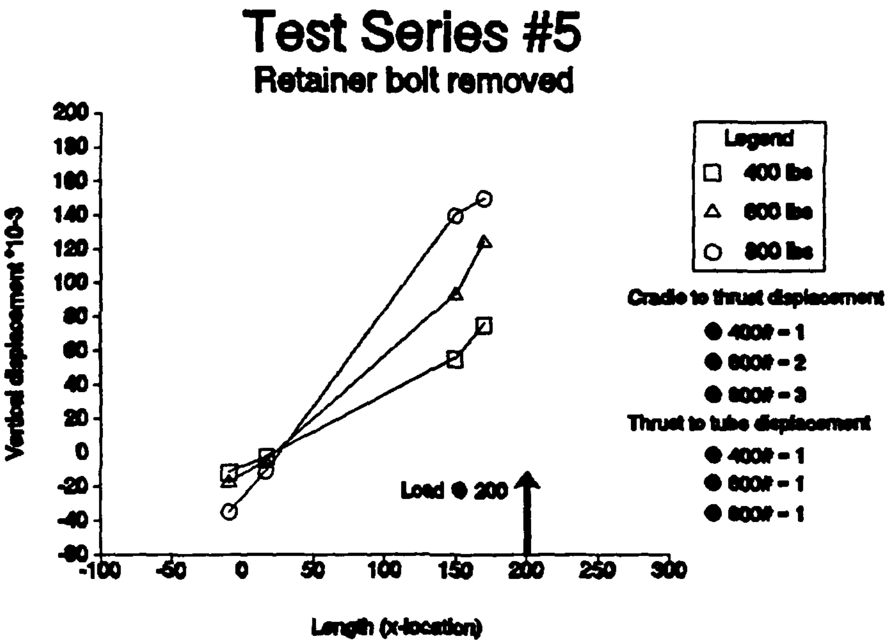

Figure 41. <u>Gun tube load 200 inches from breech end of the gun tube.</u>

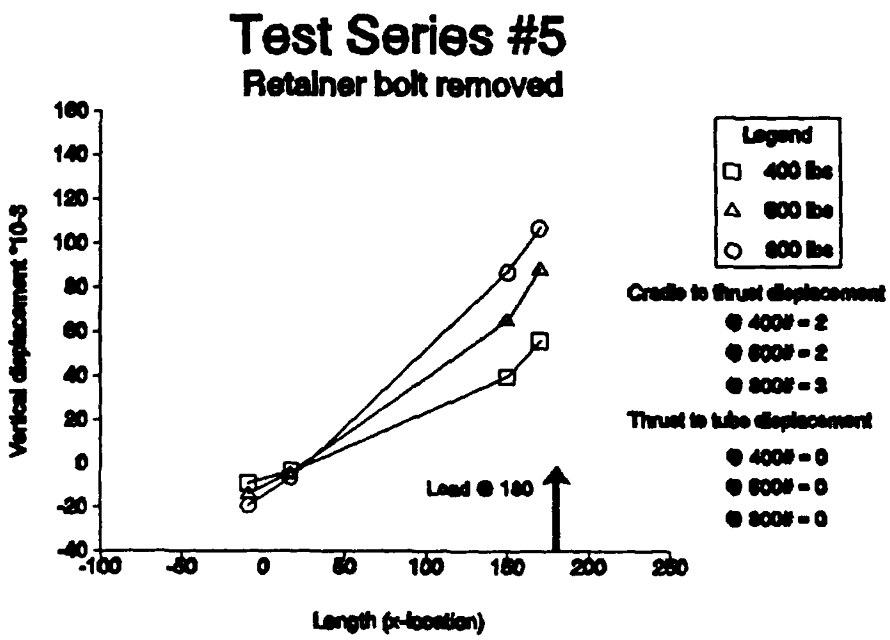

Figure 42. <u>Gun tube load 180 inches from breech end of the gun tube.</u>

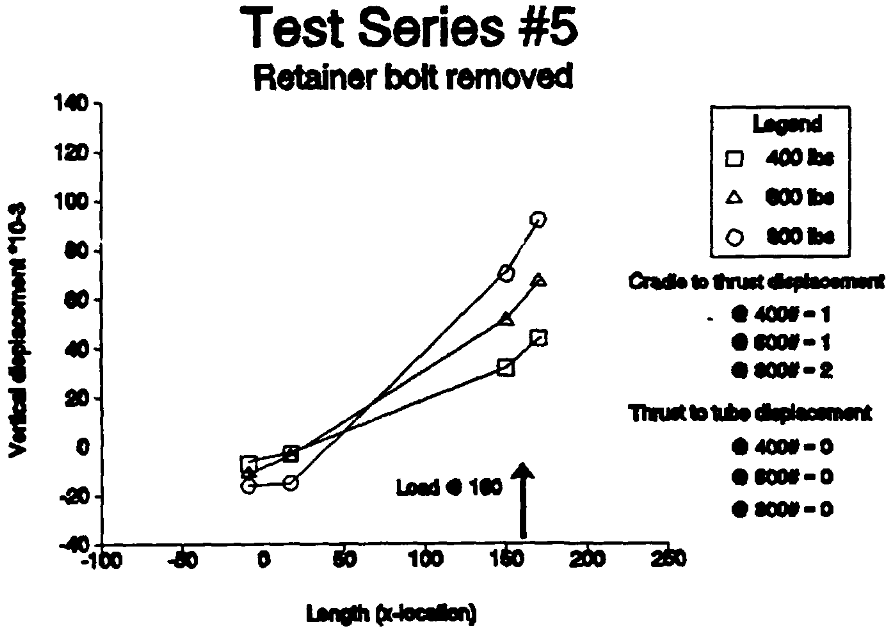

Figure 43. Gun Tube load 160 inches from breech end of the gun tube.

conclusions. However, it was recommended that on the next firing test, where eddy probe measurements are made, that these measurements include gauge locations along the cradle, in addition to the ones typically located on the breech. This will help determine whether the observed tendency of the breech to drop is caused by motion of the gun tube, piston, and breech within the cradle, or is occurring at the cradle itself.

2.6 Test Series No. 6. The last test series was done on an M256 system mounted in an M1A1 tank. In this test series, the jack screw at the elevating mechanism was not used. Rather, the actual hydraulic elevating mechanism was used. Therefore, it was understood that the spring constant used in the previous calculations would be drastically reduced. In fact, the first load level that was tried, 600 lb at the muzzle, produced displacements that completely released the dial gauges being used to measure them. Therefore, only loads of 300 lb and 500 lb were used. The results in this series are given in Figures 44 through 47. Noted in these figures is the hydraulic reservoir pressure although it is unclear whether this had any effect on the results. Additionally, values for K from the rigid body rotation are given in Appendix B. As can be seen, there is considerable scatter in this data. While the results probably give a reasonable estimate of the order of magnitude (or the linear approximation of the elevating mechanism using a spring damper system), that is the limit of their value.

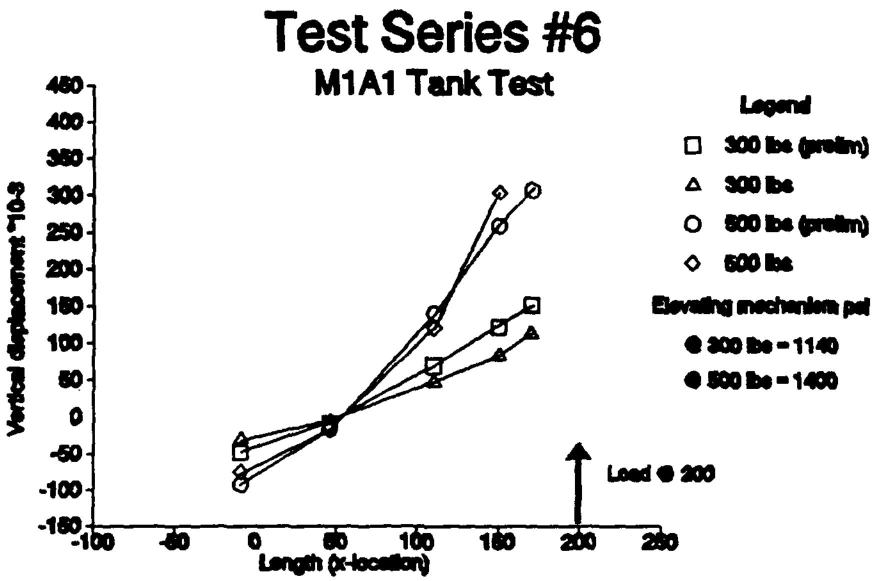

Figure 44. Gun tube load 200 inches from breech end of the gun tube.

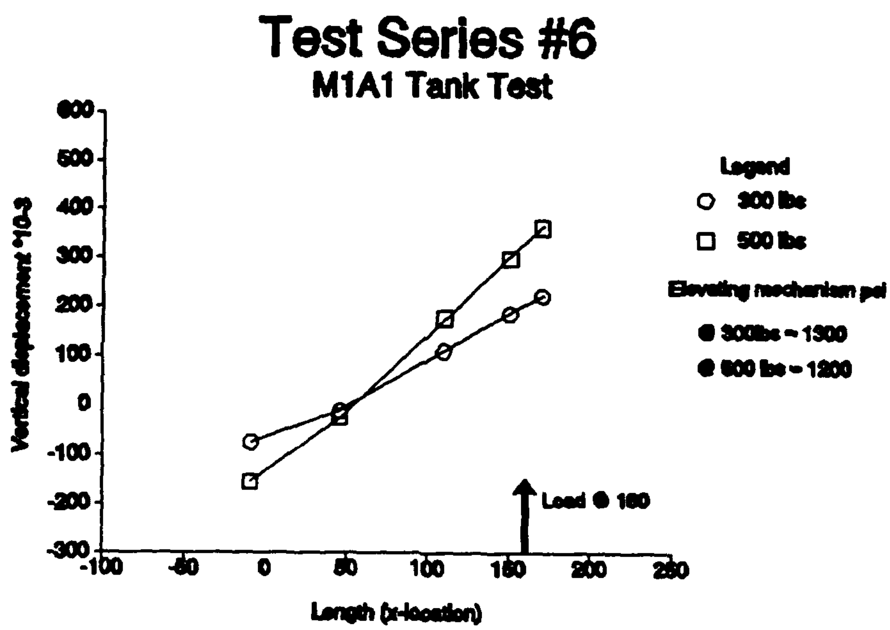

Figure 45. Gun tube load 160 inches from breech end of the gun tube.

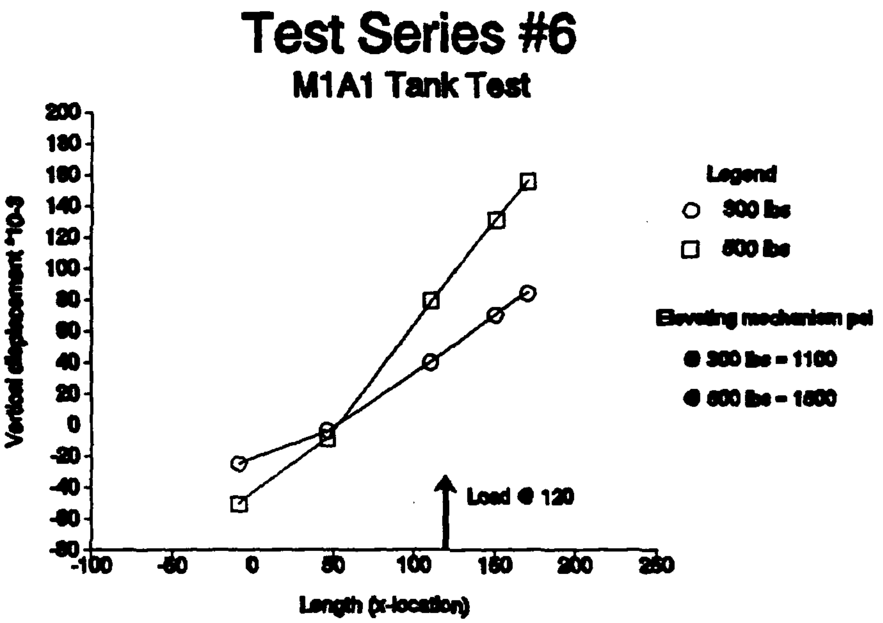

Figure 46. Gun tube load 120 inches from breech end of the gun tube.

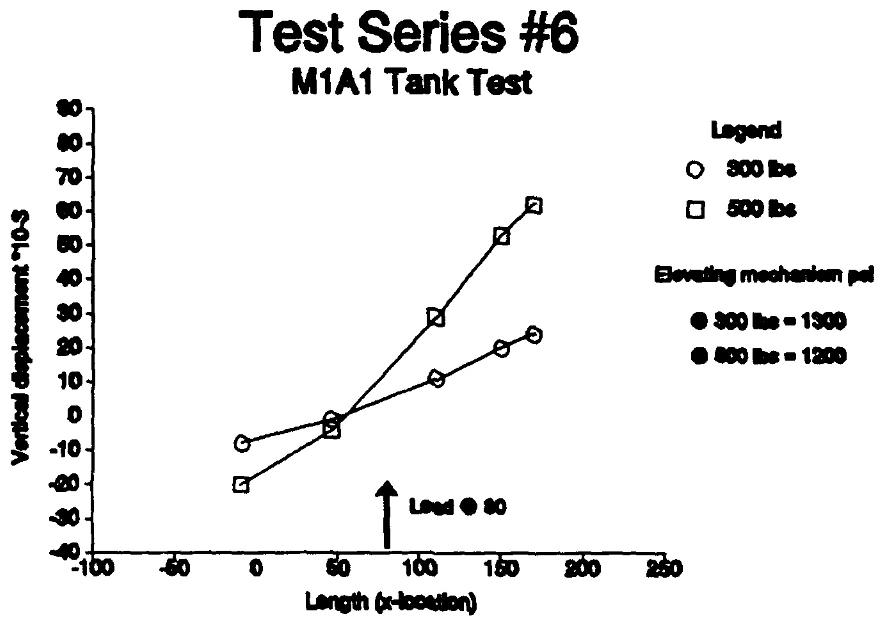

Figure 47. Gun tube load 80 inches from breech end of the gun tube.

3. CONCLUSIONS

The tests done on the M256 gun mounted in a rigid floor mount showed that the gun tube and mount underwent a rigid body rotation about the trunnions. The test further showed that the rigid body rotation occurred to a small degree due to clearances between associated parts in the system and that this phenomenon might lead to nonlinear dynamic behavior of the system. It was shown, for the simple static load case, that the system could be accurately modeled using a straight forward beam element representation. It was also shown that the rigid body rotation could be accounted for with a linear spring damper located at the elevating mechanism. Similar results and conclusions can be made from the test that was done on the M256 mounted in an M1A1 tank. However, approximating the elevating mechanism with a simple spring damper is more difficult for this case due to the large amount of scatter observed in the data as well as the limited amount of data taken. Nonetheless, valuable information concerning part connections and clearances were determined from these relative simple and inexpensive tests. For instance, it would appear from the data taken that assuming a rigid mount between the adapter, bearing, thrust nut, king nut, piston, and gun tube is a reasonable assumption. However, modeling the interfaces between the cradle and piston (the recoil mechanism) will require closer examination and imagination.

These tests also underscore the importance of conducting additional tests—namely, a modal survey of the M256 system mounted in an M1A1 tank. Simple inexpensive tests such as this one or the proposed modal survey increase knowledge about important system parameters and enable more realistic and reliable numerical models to be developed. In developing a simple or complicated finite element model of the M256 mounted in an M1A1, it is critical that the model have the same boundary conditions and geometric attributes as the actual system. Therefore, these tests help assure that both the model and actual system's response will be the same when subjected to static and/or dynamic loads. Only after these validations are accomplished is it reasonable to expect that the numerical model will predict actual observed phenomenon.

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APPENDIX A:

DISPLACEMENT GAUGE MEAUSREMENTS:

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Table A-1. Preliminary Test "A," Test Configuration: Assembled, Loaded 206 inches

Disp Gauge No.	Gauge Position	Target Load					
		200#		400#		500#	
		READ	DISP	READ	DISP	READ	DISP
1	-9	—	-10	—	-33	—	-46/-34
2	76.5	—	8	—	26	—	27/30
3	Floor[a]	—	0	—	0	—	0/0
4	120	—	25	—	80	—	83/84
5	180	—	48	—	160	—	169/168
6	200	—	81	—	162	—	179/190

[a]The floor-mounted gauge was attached to the front of the stationary stand and measured whether the platform supporting the M256 system was being moved by the applied loads.

Table A-2. Preliminary Test "B," Test Configuration: Assembled, Loaded 100 inches

Disp Gauge No.	Gauge Position	Target Load					
		200#		400#		500#	
		READ	DISP	READ	DISP	READ	DISP
1	-9	—	-4	—	-7	—	-9
2	76.5	—	3	—	6	—	7
3	Floor[a]	—	0	—	0	—	0
4	120	—	11	—	17	—	21
5	180	—	12	—	26	—	31
6	200	—	15	—	34	—	42

[a]The floor-mounted gauge was attached to the front of the stationary stand and measured whether the platform supporting the M256 system was being moved by the applied loads.

Table A-3. Test Series No. 1, Test Configuration: Assembled, Loaded 180 inches

Disp Gauge No.	Gauge Position	Target Load					
		200#		400#		600#	
		READ	DISP	READ	DISP	READ	DISP
1	-9	205	-4	380	-9	574	-14
2	76.5	207	4	382	8	578	12
3	Floor[a]	208	0	384	0	580	0
4	110	212	10	388	20	584	31
5	150	220	21	392	42	596	67
6	170	235	29	405	58	626	93

[a]The floor-mounted gauge was attached to the front of the stationary stand and measured whether the platform supporting the M256 system was being moved by the applied loads.

Table A-4. Test Series No. 1, Test Configuration: Assembled, Loaded 160 inches

Disp Gauge No.	Gauge Position	Target Load					
		200#		400#		600#	
		READ	DISP	READ	DISP	READ	DISP
1	-9	195	-3	407	-8	592	-12
2	76.5	197	3	410	7	600	11
3	Floor[a]	201	0	14	0	602	0
4	110	203	8	417	18	610	27
5	150	191	16	424	37	620	56
6	170	193	21	435	51	640	86

[a]The floor-mounted gauge was attached to the front of the stationary stand and measured whether the platform supporting the M256 system was being moved by the applied loads.

Table A-5. Test Series No. 1, Test Configuration: Assembled, Loaded 140 inches

Disp Gauge No.	Gauge Position	Target Load					
		200#		400#		600#	
		READ	DISP	READ	DISP	READ	DISP
1	-9	225	-3	400	-6	583	-10
2	76.5	227	3	402	6	590	8
3	Floor[a]	230	0	405	0	596	0
4	110	235	6	412	13	602	20
5	150	240	12	420	24	615	38
6	170	250	16	440	33	629	50

[a]The floor-mounted gauge was attached to the front of the stationary stand and measured whether the platform supporting the M256 system was being moved by the applied loads.

Table A-6. Test Series No. 1, Test Configuration: Assembled, Loaded 120 inches

Disp Gauge No.	Gauge Position	Target Load					
		200#		400#		600#	
		READ	DISP	READ	DISP	READ	DISP
1	-9	257	-3	410	-5	605	-8
2	76.5	258	3	413	+5	609	+7
3	Floor[a]	260	0	415	0	611	0
4	110	262	7	420	11	617	16
5	150	264	9	423	17	625	27
6	170	266	11	425	21	640	34

[a]The floor-mounted gauge was attached to the front of the stationary stand and measured whether the platform supporting the M256 system was being moved by the applied loads.

Table A-7. Test Series No. 1, Test Configuration: Assembled, Loaded 100 inches

Disp Gauge No.	Gauge Position	Target Load					
		200#		400#		600#	
		READ	DISP	READ	DISP	READ	DISP
1	−9	229	−2	401	−3	616	−6
2	76.5	230	2	408	3	620	5
3	Floor[a]	234	0	414	0	622	0
4	110	237	3	419	7	628	11
5	150	241	6	425	12	633	19
6	170	247	7	445	15	635	23

[a]The floor-mounted gauge was attached to the front of the stationary stand and measured whether the platform supporting the M256 system was being moved by the applied loads.

Table A-8. Test Series No. 1, Test Configuration: Assembled, Loaded 80 inches

Disp Gauge No.	Gauge Position	Target Load					
		200#		400#		600#	
		READ	DISP	READ	DISP	READ	DISP
1	−9	222	−1	390	−2	607	−3
2	76.5	224	1	392	2	615	3
3	Floor[a]	225	0	397	0	620	0
4	110	228	1	404	4	625	6
5	150	232	3	410	6	643	10
6	170	239	3	422	7	660	12

[a]The floor-mounted gauge was attached to the front of the stationary stand and measured whether the platform supporting the M256 system was being moved by the applied loads.

Table A-9. Test Series No. 1 - Retest of First Load, Test Configuration: Assembled, Loaded at 200 inches

Disp Gauge No.	Gauge Position	Target Load					
		200#		400#		600#	
		READ	DISP	READ	DISP	READ	DISP
1	-9	229	-5	454	-11	629	-17
2	76.5	230	4	457	9	633	13
3	Floor[a]	230	0	462	0	637	0
4	110	234	11	466	24	640	35
5	150	237	24	470	53	647	86
6	170	240	34	480	82	655	103

[a]The floor-mounted gauge was attached to the front of the stationary stand and measured whether the platform supporting the M256 system was being moved by the applied loads.

Table A-10. Test Series No. 2, Test Configuration: Thrust Nut Off, Loaded 180 inches

Disp Gauge No.	Gauge Position	Target Load					
		200#		400#		600#	
		READ	DISP	READ	DISP	READ	DISP
1	-9	205	-5	389	-10	573	-15
2	76.5	208	3	392	7	576	11
3	Floor[a]	209	0	394	0	579	0
4	110	212	9	398	20	582	32
5	150	218	20	403	42	595	67
6	170	230	29	413	59	609	94

[a]The floor-mounted gauge was attached to the front of the stationary stand and measured whether the platform supporting the M256 system was being moved by the applied loads.

Table A-11. Test Series No. 2, Test Configuration: Thrust Nut Off, Loaded 160 inches

Disp Gauge No.	Gauge Position	Target Load					
		200#		400#		600#	
		READ	DISP	READ	DISP	READ	DISP
1	−1	206	−3	410	−7	586	−12
2	76.5	207	2	414	6	592	10
3	Floor[a]	209	0	417	0	595	0
4	110	211	6	421	16	602	25
5	150	213	12	427	32	610	52
6	170	224	17	440	45	630	69

[a]The floor-mounted gauge was attached to the front of the stationary stand and measured whether the platform supporting the M256 system was being moved by the applied loads.

Table A-12. Test Series No. 2, Test Configuration: Thrust Nut Off, Loaded 140 inches

Disp Gauge No.	Gauge Position	Target Load					
		200#		400#		600#	
		READ	DISP	READ	DISP	READ	DISP
1	−9	236	−3	456	−7	599	−9
2	76.5	238	2	458	6	603	8
3	Floor[a]	239	0	462	0	605	0
4	110	241	7	464	15	610	21
5	150	243	13	465	27	618	41
6	170	250	17	467	38	627	53

[a]The floor-mounted gauge was attached to the front of the stationary stand and measured whether the platform supporting the M256 system was being moved by the applied loads.

Table A-13. Test Series No. 2, Test Configuration: Thrust Nut Off, Loaded at 120 inches

Disp Gauge No.	Gauge Position	Target Load					
		200#		400#		600#	
		READ	DISP	READ	DISP	READ	DISP
1	−1	252	−2	430	−5	584	−7
2	76.5	252	2	433	4	587	6
3	Floor[a]	253	0	435	0	590	0
4	110	253	6	438	11	593	16
5	150	253	10	441	19	600	28
6	170	248	12	443	25	604	36

[a]The floor-mounted gauge was attached to the front of the stationary stand and measured whether the platform supporting the M256 system was being moved by the applied loads.

Table A-14. Test Series No. 2, Test Configuration: Thrust Nut Off, Loaded at 100 inches

Disp Gauge No.	Gauge Position	Target Load					
		200#		400#		600#	
		READ	DISP	READ	DISP	READ	DISP
1	−9	236	−1	418	−3	616	−5
2	76.5	236	1	422	3	623	4
3	Floor[a]	236	0	424	0	628	0
4	110	236	2	424	6	633	11
5	150	235	3	432	9	646	16
6	170	233	4	436	12	655	21

[a]The floor-mounted gauge was attached to the front of the stationary stand and measured whether the platform supporting the M256 system was being moved by the applied loads.

Table A-15. Test Series No. 2, Test Configuration: Thrust Nut Off, Loaded at 80 inches

Disp Gauge No.	Gauge Position	Target Load					
		200#		400#		600#	
		READ	DISP	READ	DISP	READ	DISP
1	−1	224	−1	382	−2	605	−3
2	76.5	225	1	384	2	610	3
3	Floor[a]	227	0	387	0	615	0
4	110	229	2	390	4	625	7
5	150	232	3	394	6	630	11
6	170	235	4	402	8	650	14

[a]The floor-mounted gauge was attached to the front of the stationary stand and measured whether the platform supporting the M256 system was being moved by the applied loads.

Table A-16. Test Series No. 3, Test Configuration: King Nut Off, Loaded at 180 inches

Disp. Gauge No.	Gauge Position	Target Load					
		400#		600#		800#	
		READ	DISP	READ	DISP	READ	DISP
1	−9	429	−11	585	−16	833	−26
2	76.5	434	9	595	13	841	26
3	Elev. Mech[a]	425	−3	580	−4	830	−6
4	110	440	24	602	34	847	41
5	150	446	50	610	82	855	120
6	170	456	80	625	100	864	143

[a]A gauge was attached between the stationary floor mount and the elevating mechanism's bracket on the cradle. This gauge gave a good indication of whether the M256 was exhibiting rigid body displacement.

Table A-17. Test Series No. 3, Test Configuration: King Nut Off, Loaded at 160 inches

Disp Gauge No.	Gauge Position	Target Load					
		400#		600#		800#	
		READ	DISP	READ	DISP	READ	DISP
1	-9	395	-7	635	-14	736	-17
2	76.5	398	6	639	11	791	15
3	Elev. Mech[a]	391	-2	633	-4	730	-5
4	110	403	15	642	29	798	37
5	150	410	31	646	58	804	84
6	170	430	43	659	87	815	99

[a]A gauge was attached between the stationary floor mount and the elevating mechanism's bracket of the cradle. This gauge gave a good indication of whether the M256 was exhibiting rigid body displacement.

Table A-18. Test Series No. 3, Test Configuration: King Nut Off, Loaded at 140 inches

Disp Gauge No.	Gauge Position	Target Load					
		400#		600#		800#	
		READ	DISP	READ	DISP	READ	DISP
1	-9	413	-6	581	-10	787	-14
2	76.5	416	5	587	8	791	12
3	Elev. Mech[a]	410	-2	575	-3	783	-4
4	110	422	13	593	20	797	29
5	150	428	26	601	39	802	57
6	170	440	34	615	50	807	81

[a]A gauge was attached between the stationary floor mount and the elevating mechanism's bracket of the cradle. This gauge gave a good indication of whether the M256 was exhibiting rigid body displacement.

Table A-19. Test Series No. 3, Test Configuration: King Nut Off, Loaded at 120 inches

Disp Gauge No.	Gauge Position	Target Load					
		400#		600#		800#	
		READ	DISP	READ	DISP	READ	DISP
1	−9	443	−5	637	−8	818	−11
2	76.5	447	4	641	7	823	9
3	Elev. Mech[a]	438	−2	633	−2	812	−3
4	110	451	11	646	12	830	23
5	150	458	20	652	30	837	41
6	170	470	24	660	37	850	50

[a]A gauge was attached between the stationary floor mount and the elevating mechanism's bracket of the cradle. This gauge gave a good indication of whether the M256 was exhibiting rigid body displacement.

Table A-20. Test Series No. 3, Test Configuration: King Nut Off, Loaded at 100 inches

Disp Gauge No.	Gauge Position	Target Load					
		400#		600#		800#	
		READ	DISP	READ	DISP	READ	DISP
1	−9	413	−3	591	−5	794	−7
2	76.5	415	3	595	5	802	7
3	Elev. Mech[a]	410	−1	588	−1	788	−2
4	110	418	8	599	11	809	16
5	150	423	12	607	18	823	26
6	170	428	16	621	23	840	33

[a]A gauge was attached between the stationary floor mount and the elevating mechanism's bracket of the cradle. This gauge gave a good indication of whether the M256 was exhibiting rigid body displacement.

Table A-21. Test Series No. 3, Test Configuration: King Nut Off, Loaded at 80 inches

Disp Gauge No.	Gauge Position	Target Load					
		400#		600#		800#	
		READ	DISP	READ	DISP	READ	DISP
1	-9	416	-2	610	-3	830	-5
2	76.5	419	2	615	3	836	5
3	Elev. Mech[a]	413	-1	604	-1	824	-1
4	110	422	4	622	7	843	10
5	150	428	7	630	11	852	16
6	170	433	8	640	13	860	19

[a]A gauge was attached between the stationary floor mount and the elevating mechanism's bracket on the cradle. This gauge gave a good indication of whether the M256 was exhibiting rigid body displacement.

Table A-22. Test Series No. 4, Test Configuration: Assembled, Loaded at 200 inches

Disp Gauge No.	Gauge Position	Target Load							
		400#		600#		800#		1000#	
		READ	DISP	READ	DISP	READ	DISP	READ	DISP
1	-9	431	-13	625	-20	772/817	-25/-28	891	-31
2	Elev. Mech[a]	428	-3	622	-4	779/816	-6/-6	903	-7
3	Cradle to Thrust[b]	435	1	635	2	784/820	2/5	910	5
4	Thrust to Tube[c]	439	1	640	2	792/821	2/2	916	3
5	150	447	57	648	88	801/822	113/123	930	137
6	170	463	80	664	122	823/825	156/168	945	189

[a]A gauge was attached between the stationary floor mount and the elevating mechanism's bracket on the cradle. This gauge gave a good indication of whether the M256 was exhibiting rigid body displacement.

[b]A gauge was attached between the cradle and thrust nut to measure relative displacement between the cradle and piston mechanisms.

[c]A gauge was placed between the thrust nut and gun tube to measure relative displacement between the piston mechanism and gun tube. Gauge measurement was recorded 8 inches out on gun tube from gauge mount on piston.

Table A-23. Test Series No. 4, Test Configuration: Assembled Breech Lift Up, Loaded at 0.0 inches

Disp Gauge No.	Gauge Position	Target Load					
		400#		600#		800#	
		READ	DISP	READ	DISP	READ	DISP
1	−9	421	7	659	10	927	12
2	Elev. Mech[a]	410	3	647	3.5	813	4
3	Candle to Thrust[b]	426	0	638	0	790	0
4	Thrust to Tube[c]	433	0	638	0	790	0
5	150	445	−1	629	−15	780	−19
6	170	462	−14	620	−19	775	−23

[a]A gauge was attached between the stationary floor mount and the elevating mechanism's bracket on the cradle. This gauge gave a good indication of whether the M256 was exhibiting rigid body displacement.
[b]A gauge was attached between the cradle and thrust nut to measure relative displacement between the cradle and piston mechanisms.
[c]A gauge was placed between the thrust nut and gun tube to measure relative displacement between the piston mechanism and gun tube. Gauge measurement was recorded 8 inches out on gun tube from gauge mount on piston.

Table A-24. Test Series No. 5, Test Configuration: Assembled, Retainer Bolt Removed, Loaded at 200 inches

Disp Gauge No.	Gauge Position	Target Load					
		400#		600#		800#	
		READ	DISP	READ	DISP	READ	DISP
1	−9	420	−12	591	−18	797	−35
2	Elev. Mech.[a]	417	−3	594	−6.5	801	−11
3	Cradle to Thrust[b]	429	1	599	2	806	3
4	Thrust to Tube[c]	429	1	603	1	813	1
5	150	431	55	606	93	830	140
6		450	75	617	124	—	150?

[a]A gauge was attached between the stationary floor mount and the elevating mechanism's bracket on the cradle. This gauge gave a good indication of whether the M256 was exhibiting rigid body displacement.
[b]A gauge was attached between the cradle and thrust nut to measure relative displacement between the cradle and piston mechanisms.
[c]A gauge was placed between the thrust nut and gun tube to measure relative displacement between the piston mechanism and gun tube. Gauge measurement was recorded 8 inches out on gun tube from gauge mount on piston.

Table A-25. Test Series No. 5, Test Configuration: Retainer Bolt Removed, Loaded at 130 inches

Disp Gauge No.	Gauge Position	Target Load					
		400#		600#		800#	
		READ	DISP	READ	DISP	READ	DISP
1	-9	444	-9	629	-14	786	-19
2	Elev. Mech.[a]	441	-3	632	-5	784	-6
3	Cradle to Thrust[b]	446	2	635	2	787	3
4	Thrust to Tube[c]	449	0	638	0	789	0
5	150	454	40	644	65	794	87
6	170	460	56	653	88	798	107

[a]A gauge was attached between the stationary floor mount and the elevating mechanism's bracket on the cradle. This gauge gave a good indication of whether the M256 was exhibiting rigid body displacement.
[b]A gauge was attached between the cradle and thrust nut to measure relative displacement between the cradle and piston mechanisms.
[c]A gauge was placed between the thrust nut and gun tube to measure relative displacement between the piston mechanism and gun tube. Gauge measurement was recorded 8 inches out on gun tube from gauge mount on piston.

Table A-26. Test Series No. 5, Test Configuration: Assembled, Retainer Bolt Removed, Loaded at 160 inches

Disp Gauge No.	Gauge Position	Target Load					
		400#		600#		800#	
		READ	DISP	READ	DISP	READ	DISP
1	-9	433	-7	614	-11	790	-16
2	Elev. Mech.[a]	430	-3	609	-4	786	-15
3	Cradle to Thrust[b]	436	1	617	1	795	2
4	Thrust to Tube[c]	440	0	620	0	799	0
5	150	445	32	625	51	805	70
6	170	460	44	636	67	812	92

[a]A gauge was attached between the stationary floor mount and the elevating mechanism's bracket on the cradle. This gauge gave a good indication of whether the M256 was exhibiting rigid body displacement.
[b]A gauge was attached between the cradle and thrust nut to measure relative displacement between the cradle and piston mechanisms.
[c]A gauge was placed between the thrust nut and gun tube to measure relative displacement between the piston mechanism and gun tube. Gauge measurement was recorded 8 inches out on gun tube from gauge mount on piston.

Table A-27. Test Series No. 6 - M256 Gun Tube Mounted in M1A1 Tank, Test Configuration: Assembled, Loaded at 200 inches

Disp Gauge No.	Gauge Position	Target Load					
		300#			500#		
		READ	HYDRAULIC PRESS	DISP	READ	HYDRAULIC PRESS	DISP
1	-9	309/316	—/1400	-48/-30	512/522	—/1150	-92/-75
2	Trunnion[a]	309/316	—/1400	-9/-5	512/503	—/1150	-16.5/-15
3	110	309/344	—/1400	69/47	512/502	—/1150	140/121
4	150	322/322	—/1400	122/83	512/—	—/1150	259/305
5	170	323/325	—1400	151/112	513/—	—/1150	308/—

[a]A gauge was placed closer to the trunnion supports to verify the large rigid body rotation being observed at the back of the breech.

Table A-28. Test Series No. 6 - M256 Gun Tube Mounted in M1A1 Tank, Test Configuration: Assembled, Loaded at 160 inches

Disp Gauge No.	Gauge Position	Target Load					
		300#			500#		
		READ	HYDRAULIC PRESS	DISP	READ	HYDRAULIC PRESS	DISP
1	-9	270	1300	-75	511	1200	-155
2	Trunnion[a]	277	1300	-12	520	1200	-23
3	110	308	1300	111	532	1200	177
4	150	282	1300	186	530	1200	300
5	170	307	1300	223	541	1200	362

[a]A gauge was placed closer to the trunnion supports to verify the large rigid body rotation being observed at the back of the breech.

Table A-29. Test Series No. 6 - M256 Gun Tube Mounted in M1A1 Tank, Test Configuration: Assembled, Loaded at 120 inches

Disp Gauge No.	Gauge Position	Target Load					
		300#			500#		
		READ	HYDRAULIC PRESS	DISP	READ	HYDRAULIC PRESS	DISP
1	-9	314	1100	-25	491	1500	-51
2	Trunnion[a]	314	1100	-4	491	1500	-9
3	110	318	1100	40	497	1500	79
4	150	324	1100	70	501	1500	131
5	170	325	1100	84	503	1500	156

[a]A gauge was placed closer to the trunnion supports to verify the large rigid body rotation being observed at the back of the breech.

Table A-30. Test Series No. 6 - M256 Gun Tube Mounted in M1A1 Tank, Test Configuration: Assembled, Loaded at 80 inches

Disp Gauge No.	Gauge Position	Target Load					
		300#			500#		
		READ	HYDRAULIC PRESS	DISP	READ	HYDRAULIC PRESS	DISP
1	-9	307	1300	-8	509	1200	-20
2	Trunnion[a]	307	1300	-1	519	1200	-4
3	110	307	1300	11	521	1200	27
4	150	308	1300	20	524	1200	53
5	170	308	1300	24	525	1200	62

[a]A gauge was placed closer to the trunnion supports to verify the large rigid body rotation being observed at the back of the breech.

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APPENDIX B:

METHOD FOR CALCULATING ELEVATING MECHANISMS SPRING CONSTANT

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Spring Constant Calculations for Test Series 1

Load = 200# @ 180 in.

$$F_z = \frac{200\,(180 - 37.4)}{(37.4 - 16.7)} \approx 1378\,\#$$

$$y_z = \frac{.004}{46.4}\,20.7 \approx .00178$$

$$k = \frac{1378}{.00178} \approx 774{,}157$$

Load = 400# @ 180 in

$$F_z = \frac{400\,(180 - 37.4)}{(37.4 - 16.7)} \approx 2756\,\#$$

$$y_z = \frac{.009}{46.4}\,20.7 \approx .00402$$

$$k = \frac{2756}{.00402} \approx 685{,}572$$

Load = 600# @ 180 in

$$F_z = \frac{600\,(180 - 37.4)}{(37.4 - 16.7)} \approx 4133\,\#$$

$$y_z = \frac{.014}{46.4}\,20.7 \approx .00625$$

$$k = \frac{4133}{.00625} \approx 661{,}280$$

Load = 200# @ 160 in.

$$F_z = \frac{200\,(160 - 37.4)}{(37.4 - 16.7)} \approx 1185\,\#$$

$$y_z = \frac{.003}{46.4}\,20.7 \approx .00134$$

$$k = \frac{1185}{.00134} \approx 884{,}328$$

Load = 400# @ 160 in

$$F_z = \frac{400\,(160 - 37.4)}{(37.4 - 16.7)} \approx 2369\,\#$$

$$y_z = \frac{.008}{46.4}\,20.7 \approx .00357$$

$$k = \frac{2369}{.00357} \approx 663{,}585$$

Load = 600# @ 160 in

$$F_z = \frac{600\,(160 - 37.4)}{(37.4 - 16.7)} \approx 3554\,\#$$

$$y_z = \frac{.012}{46.4}\,20.7 \approx .00535$$

$$k = \frac{3554}{.00535} \approx 664{,}299$$

Spring Constant Calculations for Test Series 1 (continued)

Load = 200# @ 140 in.

$$F_2 = \frac{200\,(140 - 37.4)}{(37.4 - 16.7)} \approx 991\,\#$$

$$y_2 = \frac{.003}{46.4}\,20.7 \approx .00134$$

$$k = \frac{991}{.00134} \approx 739{,}552$$

Load = 400# @ 140 in

$$F_2 = \frac{400\,(140 - 37.4)}{(37.4 - 16.7)} \approx 1983\,\#$$

$$y_2 = \frac{.006}{46.4}\,20.7 \approx .00268$$

$$k = \frac{1983}{.00268} \approx 739{,}925$$

Load = 600# @ 140 in

$$F_2 = \frac{600\,(140 - 37.4)}{(37.4 - 16.7)} \approx 2974\,\#$$

$$y_2 = \frac{.010}{46.4}\,20.7 \approx .00446$$

$$k = \frac{2974}{.00446} \approx 666{,}816$$

Load = 200# @ 120 in.

$$F_2 = \frac{200\,(120 - 37.4)}{(37.4 - 16.7)} \approx 789\,\#$$

$$y_2 = \frac{.003}{46.4}\,20.7 \approx .00134$$

$$k = \frac{789}{.00134} \approx 588{,}806$$

Load = 400# @ 120 in

$$F_2 = \frac{400\,(120 - 37.4)}{(37.4 - 16.7)} \approx 1596\,\#$$

$$y_2 = \frac{.005}{46.4}\,20.7 \approx .00223$$

$$k = \frac{1596}{.00223} \approx 715{,}695$$

Load = 600# @ 120 in

$$F_2 = \frac{600\,(120 - 37.4)}{(37.4 - 16.7)} \approx 2394\,\#$$

$$y_2 = \frac{.008}{46.4}\,20.7 \approx .00357$$

$$k = \frac{2394}{.00357} \approx 670{,}588$$

Spring Constant Calculations for Test Series 1

Load = 200# @ 100 in.

$$F_s = \frac{200\,(100 - 37.4)}{(37.4 - 16.7)} = 605\,\#$$

$$y_s = \frac{.002}{46.4}\,20.7 = .000892$$

$$k = \frac{605}{.000892} = 678{,}251$$

Load = 400# @ 100 in

$$F_s = \frac{400\,(100 - 37.4)}{(37.4 - 16.7)} = 1210\,\#$$

$$y_s = \frac{.003}{46.4}\,20.7 = .00134$$

$$k = \frac{1210}{.00134} = 902{,}985$$

Load = 600# @ 100 in

$$F_s = \frac{600\,(100 - 37.4)}{(37.4 - 16.7)} = 1814\,\#$$

$$y_s = \frac{.006}{46.4}\,20.7 = .00268$$

$$k = \frac{1814}{.00268} = 676{,}866$$

Load = 200# @ 80 in.

$$F_s = \frac{200\,(80 - 37.4)}{(37.4 - 16.7)} = 412\,\#$$

$$y_s = \frac{.001}{46.4}\,20.7 = .000446$$

$$k = \frac{412}{} = 923{,}767$$

Load = 400# @ 80 in

$$F_s = \frac{400\,(80 - 37.4)}{(37.4 - 16.7)} = 823\,\#$$

$$y_s = \frac{.002}{46.4}\,20.7 = .000892$$

$$k = \frac{823}{.000892} = 922{,}646$$

Load = 600# @ 80 in

$$F_s = \frac{600\,(80 - 37.4)}{(37.4 - 16.7)} = 1235\,\#$$

$$y_s = \frac{.003}{46.4}\,20.7 = .00134$$

$$k = \frac{1235}{.00134} = 921{,}642$$

Spring Constant Calculations for Test Series 2

Load = 200# @ 180 in.

$$F_2 = \frac{200\,(180 - 37.4)}{(37.4 - 16.7)} \approx 1378\,\#$$

$$y_2 = \frac{.005}{46.4}\;20.7 \approx .00223$$

$$k = \frac{1378}{.00223} \approx 617,937$$

Load = 400# @ 180 in

$$F_2 = \frac{400\,(180 - 37.4)}{(37.4 - 16.7)} \approx 2756\,\#$$

$$y_2 = \frac{.010}{46.4}\;20.7 \approx .00446$$

$$k = \frac{2756}{.00446} \approx 617,937$$

Load = 600# @ 180 in

$$F_2 = \frac{600\,(180 - 37.4)}{(37.4 - 16.7)} \approx 4133\,\#$$

$$y_2 = \frac{.015}{46.4}\;20.7 \approx .00669$$

$$k = \frac{4133}{.00669} \approx 617,788$$

Load = 200# @ 160 in.

$$F_2 = \frac{200\,(160 - 37.4)}{(37.4 - 16.7)} \approx 1185\,\#$$

$$y_2 = \frac{.003}{46.4}\;20.7 \approx .00134$$

$$k = \frac{1185}{.00134} \approx 884,328$$

Load = 400# @ 160 in

$$F_2 = \frac{400\,(160 - 37.4)}{(37.4 - 16.7)} \approx 2369\,\#$$

$$y_2 = \frac{.007}{43.4}\;20.7 \approx .00312$$

$$k = \frac{2369}{.00312} \approx 759,295$$

Load = 600# @ 160 in

$$F_2 = \frac{600\,(160 - 37.4)}{(37.4 - 16.7)} \approx 3554\,\#$$

$$y_2 = \frac{.012}{46.4}\;20.7 \approx .00535$$

$$k = \frac{3554}{.00535} \approx 664,299$$

Spring Constant Calculations for Test Series 2 (continued)

Load = 200# @ 140 in.

$$F_2 = \frac{200\,(140 - 37.4)}{(37.4 - 16.7)} \approx 991\ \#$$

$$y_2 = \frac{.003}{46.4}\ 20.7 \approx .00134$$

$$k = \frac{991}{.00134} \approx 739{,}552$$

Load = 400# @ 140 in

$$F_2 = \frac{400\,(140 - 37.4)}{(37.4 - 16.7)} = 1983\ \#$$

$$y_2 = \frac{.007}{46.4}\ 20.7 \approx .00312$$

$$k = \frac{1983}{.00312} = 635{,}577$$

Load = 600# @ 140 in

$$F_2 = \frac{600\,(140 - 37.4)}{(37.4 - 16.7)} \approx 2974\ \#$$

$$y_2 = \frac{.009}{46.4}\ 20.7 \approx .00402$$

$$k = \frac{2974}{.00402} \approx 739{,}801$$

Load = 200# @ 120 in.

$$F_2 = \frac{200\,(120 - 37.4)}{(37.4 - 16.7)} \approx 798\ \#$$

$$y_2 = \frac{.002}{46.4}\ 20.7 \approx .000892$$

$$k = \frac{798}{.000892} \approx 894{,}619$$

Load = 400# @ 120 in

$$F_2 = \frac{400\,(120 - 37.4)}{(37.4 - 16.7)} \approx 1596\ \#$$

$$y_2 = \frac{.005}{46.4}\ 20.7 \approx .00223$$

$$k = \frac{1596}{.00223} \approx 715{,}695$$

Load = 600# @ 120 in

$$F_2 = \frac{600\,(120 - 37.4)}{(37.4 - 16.7)} \approx 2394\ \#$$

$$y_2 = \frac{.007}{46.4}\ 20.7 \approx .00312$$

$$k = \frac{2394}{.00312} \approx 767{,}308$$

Spring Constant Calculations for Test Series 2 (continued)

Load = 200# @ 100 in.

$$F_2 = \frac{200\ (100 - 37.4)}{(37.4 - 18.7)} = 605\ \#$$

$$y_2 = \frac{.001}{46.4}\ 20.7 = .000446$$

$$k = \frac{605}{.000446} = 1,356,502$$

Load = 400# @ 100 in

$$F_2 = \frac{400\ (100 - 37.4)}{(37.4 - 18.7)} = 1210\ \#$$

$$y_2 = \frac{.003}{46.4}\ 20.7 = .00134$$

$$k = \frac{1210}{.00134} = 902,985$$

Load = 600# @ 100 in

$$F_2 = \frac{600\ (100 - 37.4)}{(37.4 - 18.7)} = 1814\ \#$$

$$y_2 = \frac{.005}{46.4}\ 20.7 = .00223$$

$$k = \frac{1814}{.00223} = 813,453$$

Load = 200# @ 80 in.

$$F_2 = \frac{200\ (80 - 37.4)}{(37.4 - 18.7)} = 412\ \#$$

$$y_2 = \frac{.001}{46.4}\ 20.7 = .000446$$

$$k = \frac{412}{.000446} = 923,767$$

Load = 400# @ 80 in

$$F_2 = \frac{400\ (80 - 37.4)}{(37.4 - 18.7)} = 823\ \#$$

$$y_2 = \frac{.002}{46.4}\ 20.7 = .000892$$

$$k = \frac{823}{.000892} = 922,646$$

Load = 600# @ 80 in

$$F_2 = \frac{600\ (80 - 37.4)}{(37.4 - 18.7)} = 1235\ \#$$

$$y_2 = \frac{.003}{46.4}\ 20.7 = .00134$$

$$k = \frac{1235}{.00134} = 921,642$$

Load = 400# @ 180 in.

$$F_2 = \frac{400\,(180 - 37.4)}{(37.4 - 16.7)} = 2756\,\#$$

$$y_2 = \frac{.011}{46.4}\,20.7 = .00491$$

$$k = \frac{2756}{.00491} = 561{,}303$$

Load = 600# @ 180 in

$$F_2 = \frac{600\,(180 - 37.4)}{(37.4 - 16.7)} = 4133\,\#$$

$$y_2 = \frac{.016}{46.4}\,20.7 = .00714$$

$$k = \frac{4133}{.00714} = 578{,}852$$

Load = 800# @ 180 in

$$F_2 = \frac{800\,(180 - 37.4)}{(37.4 - 16.7)} = 5511\,\#$$

$$y_2 = \frac{.026}{46.4}\,20.7 = .0116$$

$$k = \frac{5511}{.0116} = 475{,}086$$

Load = 400# @ 160 in.

$$F_2 = \frac{400\,(160 - 37.4)}{(37.4 - 16.7)} = 2369\,\#$$

$$y_2 = \frac{.007}{46.4}\,20.7 = .00312$$

$$k = \frac{2369}{.00312} = 759{,}295$$

Load = 600# @ 160 in

$$F_2 = \frac{600\,(160 - 37.4)}{(37.4 - 16.7)} = 3554\,\#$$

$$y_2 = \frac{.014}{46.4}\,20.7 = .00625$$

$$k = \frac{3554}{.00625} = 568{,}640$$

Load = 800# @ 160 in

$$F_2 = \frac{800\,(160 - 37.4)}{(37.4 - 16.7)} = 4738\,\#$$

$$y_2 = \frac{.017}{46.4}\,20.7 = .00758$$

$$k = \frac{4738}{.00758} = 625{,}066$$

Spring Constant Calculations for Test Series 3 (continued)

Load = 400# @ 140 In.

$$F_2 = \frac{400\ (140 - 37.4)}{(37.4 - 16.7)} \approx 1983\ \#$$

$$y_2 = \frac{.006}{46.4}\ 20.7 \approx .00268$$

$$k = \frac{1983}{.00268} \approx 739{,}925$$

Load = 600# @ 140 In

$$F_2 = \frac{600\ (140 - 37.4)}{(37.4 - 16.7)} \approx 2974\ \#$$

$$y_2 = \frac{.010}{46.4}\ 20.7 \approx .00446$$

$$k = \frac{2974}{.00446} \approx 666{,}816$$

Load = 800# @ 140 In

$$F_2 = \frac{800\ (140 - 37.4)}{(37.4 - 16.7)} \approx 3965\ \#$$

$$y_2 = \frac{.014}{46.4}\ 20.7 \approx .00625$$

$$k = \frac{3965}{.00625} \approx 923{,}750$$

Load = 400# @ 120 In.

$$F_2 = \frac{400\ (120 - 37.4)}{(37.4 - 16.7)} \approx 1596\ \#$$

$$y_2 = \frac{.005}{46.4}\ 20.7 \approx .00223$$

$$k = \frac{1596}{.00223} \approx 715{,}695$$

Load = 600# @ 120 In

$$F_2 = \frac{600\ (120 - 37.4)}{(37.4 - 16.7)} \approx 2394\ \#$$

$$y_2 = \frac{.008}{46.4}\ 20.7 \approx .00357$$

$$k = \frac{2394}{.00357} \approx 670{,}588$$

Load = 800# @ 120 In

$$F_2 = \frac{800\ (120 - 37.4)}{(37.4 - 16.7)} \approx 3192\ \#$$

$$y_2 = \frac{.011}{46.4}\ 20.7 \approx .00491$$

$$k = \frac{3192}{.00491} \approx 650{,}102$$

Load = 400# @ 100 in.

$$F_2 = \frac{400\,(100 - 37.4)}{(37.4 - 16.7)} = 1210\,\#$$

$$y_2 = \frac{.003}{46.4}\;20.7 = .00134$$

$$k = \frac{1210}{.00134} = 902{,}985$$

Load = 600# @ 100 in

$$F_2 = \frac{600\,(100 - 37.4)}{(37.4 - 16.7)} = 1814\,\#$$

$$y_2 = \frac{.005}{46.4}\;20.7 = .00223$$

$$k = \frac{1814}{.00223} = 813{,}453$$

Load = 800# @ 100 in

$$F_2 = \frac{800\,(100 - 37.4)}{(37.4 - 16.7)} = 2419\,\#$$

$$y_2 = \frac{.007}{46.4}\;20.7 = .00312$$

$$k = \frac{2419}{.00312} = 775{,}321$$

Load = 400# @ 80 in.

$$F_2 = \frac{400\,(80 - 37.4)}{(37.4 - 16.7)} = 823\,\#$$

$$y_2 = \frac{.002}{46.4}\;20.7 = .000892$$

$$k = \frac{823}{.000892} = 922{,}646$$

Load = 600# @ 80 in

$$F_2 = \frac{600\,(80 - 37.4)}{(37.4 - 16.7)} = 1235\,\#$$

$$y_2 = \frac{.003}{46.4}\;20.7 = .00134$$

$$k = \frac{1235}{.00134} = 921{,}642$$

Load = 800# @ 80 in

$$F_2 = \frac{800\,(80 - 37.4)}{(37.4 - 16.7)} = 1646\,\#$$

$$y_2 = \frac{.005}{46.4}\;20.7 = .00223$$

$$k = \frac{1646}{} = 738{,}117$$

Spring Constant Calculations for Test Series 4

Load = 400# @ 200 In.

$$F_2 = \frac{400\,(200 - 37.4)}{(37.4 - 16.7)} = 3142\,\#$$

$$y_2 = \frac{.013}{46.4}\,20.7 = .00580$$

$$k = \frac{3142}{.00580} = 541{,}724$$

Load = 600# @ 200 In

$$F_2 = \frac{600\,(200 - 37.4)}{(37.4 - 16.7)} = 4713\,\#$$

$$y_2 = \frac{.020}{46.4}\,20.7 = .00892$$

$$k = \frac{4713}{.00892} = 528{,}363$$

Load = 800# @ 200 In

$$F_2 = \frac{800\,(200 - 37.4)}{(37.4 - 16.7)} = 6284\,\#$$

$$y_2 = \frac{.025}{46.4}\,20.7 = .0112$$

$$k = \frac{6284}{.0112} = 561{,}071$$

Load = 1000# @ 200 In.

$$F_2 = \frac{1000\,(200 - 37.4)}{(37.4 - 16.7)} = 7855\,\#$$

$$y_2 = \frac{.031}{46.4}\,20.7 = .0138$$

$$k = \frac{7855}{.0138} = 569{,}203$$

Spring Constant Calculations for Test Series 5

Load = 400# @ 200 In.

$$F_2 = \frac{400\ (200 - 37.4)}{(37.4 - 16.7)} = 3142\ \#$$

$$y_2 = \frac{.012}{46.4}\ 20.7 = .00535$$

$$k = \frac{3142}{.00535} = 587{,}920$$

Load = 600# @ 200 In

$$F_2 = \frac{600\ (200 - 37.4)}{(37.4 - 16.7)} = 4713\ \#$$

$$y_2 = \frac{.018}{46.4}\ 20.7 = .00803$$

$$k = \frac{4713}{.00803} = 586{,}924$$

Load = 800# @ 200 In

$$F_2 = \frac{800\ (200 - 37.4)}{(37.4 - 16.7)} = 6284\ \#$$

$$y_2 = \frac{[illegible]}{46.4}\ 20.7 = [illegible]$$

$$k = \frac{6284}{.0156} = 402{,}821$$

Load = 400# @ 180 In.

$$F_2 = \frac{400\ (180 - 37.4)}{(37.4 - 16.7)} = 2756\ \#$$

$$y_2 = \frac{[illegible]}{46.4}\ 20.7 = [illegible]$$

$$k = \frac{2756}{.00402} = 685{,}572$$

Load = 600# @ 180 In

$$F_2 = \frac{600\ (180 - 37.4)}{(37.4 - 16.7)} = 4133\ \#$$

$$y_2 = \frac{.014}{46.4}\ 20.7 = .00625$$

$$k = \frac{4133}{.00625} = 661{,}280$$

Load = 800# @ 180 In

$$F_2 = \frac{800\ (180 - 37.4)}{(37.4 - 16.7)} = 5511\ \#$$

$$y_2 = \frac{.019}{46.4}\ 20.7 = .00848$$

$$k = \frac{5511}{.00848} = 649{,}882$$

Spring Constant Calculations for Tes` Series 5 (continued)

Load = 400# @ 180 in.

$$F_2 = \frac{400\,(180 - 37.4)}{(37.4 - 16.7)} \approx 2758\,\#$$

$$y_2 = \quad \approx .003$$

$$k = \frac{2758}{.003} \approx 918{,}667$$

Load = 600# @ 180 in

$$F_2 = \frac{600\,(180 - 37.4)}{(37.4 - 16.7)} \approx 4133\,\#$$

$$y_2 = \quad \approx .005$$

$$k = \frac{4133}{.005} \approx 826{,}600$$

Load = 800# @ 180 in

$$F_2 = \frac{800\,(180 - 37.4)}{(37.4 - 16.7)} \approx 5511\,\#$$

$$y_2 = \quad \approx .006$$

$$k = \frac{5511}{.006} \approx 918{,}500$$

Load = 300# @ 200 in.

$$F_2 = \frac{300\,(200 - 37.4)}{(37.4 - 18.7)} = 2357\,\#$$

$$y_2 = \frac{.048}{46.4}\,20.7 = .0214$$

$$k = \frac{2357}{.0214} \approx 110{,}000$$

Load = 500# @ 200 in

$$F_2 = \frac{500\,(200 - 37.4)}{(37.4 - 18.7)} = 3928\,\#$$

$$y_2 = \frac{.092}{46.4}\,20.7 = .0410$$

$$k = \frac{3928}{.0410} = 95{,}704$$

Load = 300# @ 160 in.

$$F_2 = \frac{300\,(160 - 37.4)}{(37.4 - 18.7)} = 1777\,\#$$

$$y_2 = \frac{.075}{46.4}\,20.7 = .0335$$

$$k = \frac{1777}{.0335} = 53{,}108$$

Load = 500# @ 160 in

$$F_2 = \frac{500\,(160 - 37.4)}{(37.4 - 18.7)} = 2961\,\#$$

$$y_2 = \frac{.155}{46.4}\,20.7 = .0692$$

$$k = \frac{2961}{.0692} = 42{,}800$$

Spring Constant Calculations For Test Series 6 (continued)

Load = 300# @ 120 In.

$$F_2 = \frac{300\,(120 - 37.4)}{(37.4 - 16.7)} \approx 1197\,\#$$

$$y_2 = \frac{.025}{46.4}\,20.7 \approx .0112$$

$$k = \frac{1197}{.0112} \approx 107{,}354$$

Load = 500# @ 120 In

$$F_2 = \frac{500\,(120 - 37.4)}{(37.4 - 16.7)} \approx 1995\,\#$$

$$y_2 = \frac{.051}{46.4}\,20.7 \approx .0228$$

$$k = \frac{1995}{.0228} \approx 87{,}692$$

Load = 300# @ 80 In.

$$F_2 = \frac{300\,(80 - 37.4)}{(37.4 - 16.7)} \approx 617\,\#$$

$$y_2 = \frac{.008}{46.4}\,20.7 \approx .00357$$

$$k = \frac{617}{.00357} \approx 172{,}878$$

Load = 500# @ 80 In

$$F_2 = \frac{500\,(80 - 37.4)}{(37.4 - 16.7)} \approx 1029\,\#$$

$$y_2 = \frac{.02}{46.4}\,20.7 \approx .00892$$

$$k = \frac{1029}{.00892} \approx 115{,}333$$

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